W. B. No. 875

U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

MONTHLY WEATHER REVIEW

VOLUME 53, No. 7

JULY, 1925

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

JULY, 1925

CONTENTS

CONTRIBUTIONS, ABSTRACTS, AND BIBLIOGRAPHY

WEATHER OF THE MONTH

WEATHER OF THE MONTH—Continued

CHARTS

CORRECTION

REVIEW, September, 1924, vol. 52:

On page 447, Table 1, under heading "August," 27 should be 17.

† In marine separate.

MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY. Assistant Editor, BURTON M. VARNEY.

VOL. 53, No. 7
W. B. No. 875

JULY, 1925

CLOSED SEPT. 3, 1925
ISSUED SEPT. 30, 1925

ON THE QUESTION OF DAY-TO-DAY FLUCTUATIONS IN THE DERIVED VALUES OF THE SOLAR CONSTANT

By C. F. MARVIN

[Washington, September 2, 1925]

SYNOPSIS

Frequent use is made of the short term "solar constant" to denote the derived values of the intensity, expressed in appropriate thermal units, of solar radiation as if measured just outside the atmosphere of the earth when at its mean distance from the sun.

Determinations of the solar constant show small but important fluctuations from day to day. This investigation is a search for evidence as to what part, if any, of these and of other short-period fluctuations, should be ascribed to solar changes, and what part, if not all, must be assigned to the inevitable errors of derivation.

Unusual methods of analysis are required, because the total variation due to all causes is so small that it is entirely plausible that all of it may be nothing but errors of measurement. At the same time it is possible some solar variation may exist.

SECTION I. The mathematical equations for computing the solar constant are given with extensions drawn from statistical theorems for impersonally measuring, comparing, and correlating variations in observational data.

SEC. II. Securing highly accurate values of the solar constant in absolute magnitude is a difficult problem by itself and is wholly foreign to this study.

Evidence for and against day-to-day and other variations in solar intensity can be secured from pyrheliometer readings alone.

How this is done is shown by a sample analysis of the latest and best observations thus far published in full, namely, for Calama, Chile, July, 1918, to July, 1919. The pyrheliometer is the basic instrument for all solar constant measurements. Its errors are smallest, most certainly known and most constant, and when properly standardized it is the most comparable of all the instruments employed.

It is not difficult to show that nothing but the sun and errors of derivation can cause variations of the solar constant at a single station. If half the total variation found at Calama is assumed to be due to the sun, analysis shows the probable departure of any daily value from the mean for the year due to the sun to be ± 0.0083 calorie. To ascribe this small possible variation to the sun is to assume that the total variation at the Calama station due to all causes is the irreducible minimum of total variation to be found when values are available from many equally good stations.

SEC. III. A graphical tabulation is given to aid in the interpretation of correlations between pyrheliometer and other observations.

SEC. IV. Consecutive values of solar constant values from 1902 to 1924 are charted and probable variations evaluated and illustrated.

SEC. V. Any annual periodicity in solar constant values is prima facie evidence of terrestrial influence. Small but important summer and winter effects of this kind based on fully 3,000 daily values are shown in a striking manner, including the physically inconsistent values for the station at Harqua Hala, which are found to be correlated with the values at Montezuma in an artificial way.

SEC. VI. An example is given of how solar variations can be segregated from variations due to errors, when simultaneous observations are available from one or more pairs of independent stations by the solution of three simultaneous equations between solar variation and the two other unknown variations caused by station errors. Incidentally, it is shown how to ascertain whether the three unknowns are interdependent and thus how to interpret in a rational way the results secured.

INTRODUCTION

For a period of more than 20 years the Astrophysical Observatory of the Smithsonian Institution has been securing observations of the thermal intensity of the sun's radiation as if measured just outside the atmosphere of the earth when at mean solar distance. The derivation of such results from observations made at the bottom of our atmosphere, even when stations are located on mountain tops or high plateaus, is beset with serious and uncontrollable errors due to the clearing up or hazing up of the local atmosphere resulting from the everchanging states of dust, water content, and turbidity of the air column through which the incoming radiation must pass before reaching the measuring instruments.

The frequency of such observations and their order of accuracy have steadily increased. Values of the solar constant are now being secured by the Astrophysical Observatory from one or both of two stations in opposite hemispheres, one at Montezuma, Chile, about latitude 22° 28′ S., longitude 68° 56′ W., altitude nearly 10,000 feet; the other at Harqua Hala, Ariz., latitude 33° 45′ N., longitude 115° 15′ W.; altitude 5,680 feet. It is reported that plans are in hand to establish a third station at some suitable place in the Eastern Hemisphere.

The best observations by the so-called long or Langley bolographic method show a probable variation due to all causes of less than 1 per cent of the total intensity. Values obtained by a short method using an empirical instrument known as the pyranometer show a probable variation of less than one-half of 1 per cent.

In the making of some kinds of measurements we know with certainty beforehand that the quantity we measure remains indefinitely constant within the limits of precision of our measures. We then properly attribute all observed variations to errors of determination. In many other kinds of measurements, well illustrated by determinations of the solar constant, we are in doubt. Some of the observed small changes may be due to something besides errors of determination, as in this case to the sun itself. If such changes were large as compared with the unknown errors, little or no uncertainty would arise. On the other hand, if the possible solar changes are so small as to be incapable of direct measurement and individual identification, then very unusual statistical methods must be invoked to get at the facts, that is, to disentangle the small hidden solar variations from the total due to all causes.

As soon as good values of the solar constant were obtained, the claim for important day-to-day changes in solar intensity began to be made. No one, however, so far as I am aware, has made the unusual kind of analysis required to prove that such day-to-day fluctuation was partly of solar origin. The problem is necessarily a difficult and more or less inconclusive one.

Ten years ago, when the claims for solar variation began to be confidently asserted, the statistically measured total variation of high-grade observations was about 1.2 per

cent. If a skeptic of that day had conceded that *half of this statistically measured total* might be ascribed to the sun he would to-day be facing the unpleasant reductio ad absurdum that the *part* formerly conceded is now greater than the *whole*, so greatly has this whole been reduced in the latest high grade observations.

Notwithstanding all such representations as the foregoing, Doctor Abbot is convinced that his observations show important systematic changes of solar intensity from day to day, week to week, etc. He is further convinced that studies by Mr. Clayton show important correlations between the values of the solar constant and the weather at various places on the surface of the earth, of such a nature that despite all their errors, the changing values of the solar constant become a trustworthy basis for short and long range forecasts of the weather.[1]

The interest of the Weather Bureau in these investigations has constantly been very great, and it has examined with special care the values of the solar constant as these have been published at intervals by the Astrophysical Observatory of the Smithsonian Institution. Its studies are necessarily based only upon the final values as published, which are but a fragment of the mass of original observations, and in these published data the Bureau fails to find a sufficient basis for the view that short-period solar fluctuations do exist. Even conceding the possibility that a *part* of the present small total variation due to all causes may be ascribed to the sun, it must still be shown that this part exists, and, small as it certainly is, that it is physically sufficient to cause direct daily effects upon the weather of such a magnitude that they have a value in weather forecasting.

These considerations show how necessary it is that the analysis be made without further delay.

There are, no doubt, astronomers and meteorologists who may, without themselves undertaking a critical analysis of the observational data, tacitly accept at their full face value the published claims for important solar variability from day to day and who may wonder as to the forecasting possibilities of such a characteristic of solar activity.

It would be quite unwarranted to say that the thermal radiation of the sun is unchangeable from day to day, or from season to season. In the face of all that has been revealed as to the sun's physical features and activity in the way of spots, flocculi, faculae, coronal streamers, prominences, etc., there are abundant physical grounds for suspecting that changes of intensity of radiation are occurring all the time. Accordingly, if accurate observations of the solar constant had never been made, claims of day-to-day and other variations could not be questioned or refuted. Fortunately, however, a very large body of highly accurate values of the solar constant are accessible in the publications of the Astrophysical Observatory.

For the information of many who doubtless would like to know quantitatively the significance of such day-to-day fluctuations as may exist, it is the purpose of this study to examine the mute testimony of the published data, as nearly as the nature of these data permits.

Observations[2] of varying exactitude have been secured since the early efforts during the years 1902 to 1907 to develop apparatus and methods, at Washington, D. C. Here the sky conditions were usually highly unfavorable, and naturally the variations of derived values of the solar constant were rather great. Serious observational work began, however, in 1905, when a station equipped with pyrheliometer and bolograph was established at Mount Wilson, Calif.

The observations are not, of course, all of equal excellence. Doctor Abbot has characterized them[3] as follows:

> Really, to speak in a figure, the Washington data of 1902 to 1907 were Prehistoric. As for Mount Wilson results of 1905 to 1908, inclusive, before the invention of the silver disk pyrheliometer, or Fowle's method for estimating total atmospheric humidity, and while we yet used a flint glass prism limiting our spectrum at the H and K lines in the violet—this work is Ancient. Excluding altogether July and August, 1912, the year of the eruption of the Katmai volcano, all Mount Wilson work of 1909 to 1920 can be classed as Medieval. We had then but one station, operating only in summer. We obtained only one determination per day, subject to error from changes of sky transparency and also to errors of computing in the enormous multiplicity of computations used in the reductions of results by Langley's fundamental method. The period from January, 1919, to the present is of another order of accuracy, and represents the Modern period.
>
> All of the Mount Wilson work, excluding altogether July and August, 1912, is useful in the form of averages. It is only since January, 1919, when we have had several determinations each day by a method [pyranometer,-*C.F.M.*] which avoids errors from the variability of the sky, and much of the time have received results from two stations, that individual values have begun to deserve some confidence.

Notwithstanding this severe disparagement of the bolographic and older work, we have long marveled at the general high order of accuracy secured by Doctor Abbot, not excepting even those observations which were influenced by Katmai dust during 1912 and 1913. Here, fortunately, we have positive evidence, which only a violent volcanic eruption could produce, of the extent to which atmospheric influence on incoming radiation can cause spurious variations of the solar constant.

The systematic observations with the pyranometer fall in a class by themselves and have a probable variation of less than half that of values secured by the bolograph. Nevertheless, the pyranometer is entirely an empirical instrument and its absolute accuracy can not be as great in the long run as that of the bolograph, from which all the empirical coefficients of the pyranometer must be derived.

Mr. Clayton makes extensive use of the Mount Wilson bolographic observations for the years 1913, 1915, and 1918, often in small groups of extreme values only, to establish his correlations of supposed changes of solar constant with weather changes. Accordingly, we also shall use these data, but only in the form of monthly and annual averages, the accuracy of which is much greater than that of single or even of several daily values, especially when the latter, chosen because they are extreme, are therefore most likely to be affected by error larger than the mean error.

Our analysis must speak for itself as to its sufficiency and soundness, but we are glad to emphasize that the general high excellence of the observational data not only justifies but invites critical statistical examination, and rewards the effort by gratifying consistency and definiteness in the results obtained.

There is no pretense in this paper to an exhaustive analysis of all the pros and cons of variations in the sun's thermal radiations. We confine our analysis to a single problem:

In the derived day-to-day values of the solar constant are found greater or lesser irregular changes. What part of these, if any, is due to changes in solar intensity, and what part to wholly unavoidable atmospheric influences and other errors of measurement?

[1] Report on the Astrophysical Observatory, 1924, Appendix 7. Abbot, C. G., Solar variation and forecasting. Smiths. Misc. Coll., vol. 77, no. 3, 1925.

[2] Abbot, C. G., and colleagues. Annals of the Astrophysical Observatory of the Smithsonian Institution, Vol. III, 1913, Vol. IV, 1922, and Provisional Values of the Solar Constant, August, 1920, to November, 1924, Smithsonian Miscellaneous Collections, vol. 77, no. 3.

[3] Abbot, C. G., Solar Variation and Forecasting. Smiths. Misc. Coll., vol. 77, no. 5, pp. 2-3.

Fully alert to the great meteorological importance of consequential changes in the solar constant over both short and long periods of time, *we regard it as of paramount importance to seek out a quantitative answer to the question proposed. It is futile to hope to establish any scientific basis for weather forecasting on supposed changes of solar constant before we know that the constant does change from day to day, and if it does, how much.*

The discussion in Chapter V of Volume IV of Annals of the Astrophysical Observatory on methods for evaluating errors, is unsatisfactory and misleading because, pointing out the numerous ways in which errors can occur, it assigns to some of them very approximate values, and even these are based on special and individual cases. The only acceptable measure of errors affecting observations for, say, a whole year, under all kinds of atmospheric conditions, is some such measure of fluctuation as the standard deviation. This definite statistical index of scatter of the derived values measures all the variations. Adequate statistical proof must support any claim that part of them are of solar origin.

This preliminary analysis necessarily must deal with the short-period solar changes, leaving the long-period, slow, progressive changes to be dealt with in later studies.

The subject will be discussed under the following captions:

I. Theoretical considerations.
II. Analysis of pyrheliometer readings at Calama, Chile, using standard deviations.
III. Analysis of Calama data by correlations.
IV. General examination of the variability of all values of the solar constant by bolograph and pyranometer.
V. The 12-month period in solar constant values for northern and southern hemispheres.
VI. Solar variations computed from observations at independent stations.
VII. Conclusion.

I. THEORETICAL CONSIDERATIONS

SYMBOLS AND NOMENCLATURE

a_λ. Coefficient of transmission of the air for monochromatic thermal radiation of the sun of wave length λ.

a. Apparent coefficient of transmission for polychromatic radiation as measured by pyrheliometers and black body absorbers of total radiation.

I_1, I_2, I_3. Intensities outside the atmosphere of various spectral beams of monochromatic radiation.

I_0. The true errorless intensity of total solar radiation outside the atmosphere $= I_1 + I_2 + I_3 + \ldots$, the true solar constant.

m. Relative air mass at the same station as dependent upon the sun's zenith distance.

z. Angular distance of sun from zenith at time of an observation.

$p.\ w.$ Atmospheric moisture measured as precipitable water.

$A_1, A_2 \ldots A_m$. Intensities of total radiation at a station as measured by the pyrheliometer or like instrument at different air masses $1, 2 \ldots m$

i_1, i_2, i_3 intensities of the radiations I_1, I_2, I_3, etc., after transmission through air mass m.

$h_1, h_2 \ldots h_3$. The height in millimeters or other *linear* unit of the ordinates on the bolographic trace or energy spectrum curve as observed. Such ordinates are deemed sufficient to show the *relative* thermal intensities in the solar spectrum, and by summation, after the application of a complicated series of corrections, are regarded as directly proportional to simultaneously observed values of the pyrheliometer A_m.

E_0. The Smithsonian Institution's symbol representing the *solar constant*, including all its errors of terrestrial origin.

$\bar{A}_0$. A convenient and helpful analytical quantity which satisfies a certain equation given later. In familiar language, it is a hybrid solar constant found by the extrapolation of logarithms of pyrheliometer observations at different air masses to zero air mass by the straight line of best fit. The significance of the quantity is purely analytical, not physical.

A_s, A_q. Values for the solar constant obtained as explained in Table 2. Their significance is purely analytical, not physical.

NOTE.—Each of the foregoing quantities representing thermal intensities is subject to a variation depending upon the earth's distance from the sun at the time. All such variations are assumed to be completely excluded from data before analysis, by reduction to the earth's mean solar distance.

The following symbols relate to fluctuations and their statistical measurements:

σ, Standard deviation, occasionally called scatter and based on departures from the mean.

t, x, y, i, as subscripts, signify the causes of the fluctuations, as total causes, errors at stations X or Y, and due to sun, respectively.

V, the variate difference, the difference between consecutive values.

ΔI_0 represents the variate difference between real solar intensities.

In $\bar{E}_0$, $\bar{V}$, $\bar{V^2}$, $\overline{\Delta I^2}$, the superior bar indicates that these are mean values.

v, a departure from a mean value, a residual.

md the mean deviation or the average sum of departures from the mean without regard to sign.

According to the well-known Bouguer-Langley exponential law of atmospheric transmission of radiation, a single beam of monochromatic radiation of original intensity I_1 will have an intensity, i_1, at the bottom of an air mass m, given by the equation

$$i_1 = I_1 a_1^m \quad (1)$$

in which a_1 is the coefficient of transmission for radiation of the particular wave length of the beam in question.

Now, solar radiation is polychromatic; whence, there are many beams of varying wave lengths and varying intensities $I_1, I_2, I_3, \ldots$ etc., each with its appropriate coefficient of transmission $a_1\ a_2\ a_3$, etc. After transmission through air mass m these have the several intensities—

$$I_1\, a_1^m,\ I_2\, a_2^m,\ I_3\, a_3^m \quad \ldots, \text{etc.}$$

When properly standardized, the pyrheliometer measures the total thermal radiation transmitted to its place of exposure at the bottom of the ocean of atmosphere. If this total for a given air mass m is A_m, then

$$A_m = I_1\, a_1^m + I_2\, a_2^m + I_3\, a_3^m + \ldots \quad (2)$$

and if the original intensity of the total radiation is I_0 then

$$I_0 = I_1 + I_2 + I_3 + \ldots \quad (3)$$

Equation (1) is widely accepted as rigorously exact and accordingly constitutes a satisfactory analytical basis for the present effort to evaluate from the actual observations day-to-day and other frequent short-interval variations of

solar radiation. Any such variations must express themselves, first, as variations in I_1, I_2, ---- etc., either separately or collectively. If they do not at once neutralize and nullify each other, all such variations, however they may occur, must reflect themselves as variations in I_0 and A_m or other observations of radiant intensity that we may be able to make. Equation (1) establishes definite functional and extremely simple relations between the one dependent variable A, (dropping the subscript m) and the three wholly independent variables m, $I_0 = \Sigma I_\lambda$ and Σa_λ. It is fortunate that apart from the irregular variations we call errors, equation (1) seems to include every known cause of variation affecting the quantities involved. Moreover, as will appear later, when the quantities are in logarithmic form the relations become strictly linear and therefore greatly facilitate correlation and render the interpretation of correlation coefficients the more definite.

Of the three independent variables, m is the only one that is under even partial human control. If we can observe the pyrheliometer at a particular station with the sun exactly in the zenith, then we may assign to m the value 1. If the sun is at an angle z from the zenith, then $m = \sec z$ (approximately). We still remain ignorant of any mathematical function by which to equate air masses at one station with those at far distant stations.

The variables I_1, I_2 ---- a_1, a_2 ----, etc. in equation (2) are independent. The sun alone controls the values of I_1, I_2, I_3, ----, etc. On the other hand the coefficient of air transparencies a_1, a_2, a_3 represent constantly changing conditions of the earth's atmosphere, not directly ascribable to the sun and wholly beyond any human control except such as may be expressed by a choice as to where and when we make pyrheliometric readings.

It is plain that there is no rigorous and at the same time workable transformation between (2) and (3) by which I_0 can be equated directly to A_m and the other variables. However, it has long been known that equation (1) for monochromatic radiation can be used also with polychromatic radiation, either by disregarding a small outstanding variable, p, due to polychromatic radiation, or, as we prefer to do, by writing p into the equations for ultimate evaluation. This course is especially appropriate in analyzing observations from stations at various high altitudes overlain by the driest, most transparent air masses possible to attain. In such cases $a_1^m\ a_2^m\ a_3^m$, etc., are most nearly unity and A_m approaches I_0; that is, p, seemingly best expressed as a ratio, is then nearly constant and nearly equal to 1.

These considerations give, after dropping the subscript m,

$$A = A_0\ a^m \qquad (4)$$

$$A_0 p = I_0 = \frac{i_1}{a_1^m} + \frac{i_2}{a_2^m} + \frac{i_3}{a_3^m} + ---- \qquad (5)$$

In (4) a is now the apparent transmission coefficient for the whole polychromatic beam of radiation measured by the pyrheliometer. In (5) $p = \frac{I_0}{A_0}$ is the new variable ratio permitting A_0 to be equated to I_0, which here represents not an observation, but the true solar constant as an independent variable. A_0 in (4) and (5) has no real physical significance and is simply the value of A in (4) when $m = 0$.

The quantity p can not be evaluated from pyrheliometric observations at a single station, but we are now concerned only with variations in A_0 and p and it will suffice to replace p by a constant value p_0 and a variable part which for all practical purposes can be classed as part of the unavoidable errors of observations, as will appear later.

Writing equation (4) in logarithmic form we get

$$\log A = \log A_0 + m \log a \qquad (6)$$

and by the familiar straight line extrapolation of low and high sun observations of A to zero air mass we get values of A_0 and a.

Pyrheliometry.—Up to this point all equations are as rigorously exact as the Bouguer-Langley law of atmospheric transmission permits. Each term is regarded as an errorless value or fact. Now, however, we must pass to fallible human observations of the pyrheliometer and other inexact measurements of A_0, m, and a. Indeed, in evaluating A_0 and a in (6) by low and high sun observations, we make an assumption which both reason and experience tells us can rarely or never be satisfied, namely, that *both I_0 and a remain constant during the several hours required to make the necessary low and high sun observations of A.* If the *transparency of the air* and the *solar intensity* change irregularly *from day to day*, how futile it is to assume, as we are prone to do, that these variables obligingly remain constant during several hours each day while we make observations of intensity at different air masses. Every failure of the assumption to be satisfied is necessarily and faithfully extrapolated to zero air mass as an error, and there it appears to be a fluctuation of the solar constant whether the result is A_0 or E_0, because of course the bolograph is powerless to exclude errors due to a fallacious assumption about the constancy of the atmosphere or of the sun.

Few observations made anywhere in the world are quite free from evidences of this insidious cause of error, of which at least a part must be ascribed to the sun if we insist upon appreciable day-to-day changes of solar intensity.

High grade pyrheliometer readings clearly show that measurements of total polychromatic radiation at different air masses require a *curved* line to properly represent their trend and that for equation (6) we should write

$$y = y_0 + b\ m + c\ m^2 \qquad (7)$$

in which the logarithms are represented by the simple letters y, y_0, b and c. A part of this curvature can be ascribed to the complete extinction of some radiation at times of low-sun observations. While the effect of such losses is small, the question deserves more careful examination than it seems to have received thus far.

Analytical relations can be shown justifying the use of a power series to represent polychromatic radiation and equation (7) introduces the first term of such a series. A very few trials show that such a quadratic equation fits group mean values in a highly satisfactory way. The equation, however, is all but worthless for the extrapolation of *daily* values, because the large variations in such observations caused by the failure of a or I_0 or both to remain constant gives entirely spurious values to b and c. Moreover, the intercept y_0 at air mass zero has no physical meaning. Quantitatively, it is like A_0 in equation (4). It is simply the value of y in equation (7) when $m = 0$.

Notwithstanding these limitations, equation (7) promises to be highly useful in the analysis of large group values of data for the study of long-interval changes in I_0.

Bolometry.—The series of terms i_1, i_2, i_3, etc., in equation (5) represents the intensities of the numerous beams of monochromatic radiation as they reach the bolograph and there represent the energy of the solar spectrum on the bolographic trace. It is impossible to measure these intensities except in a purely relative way, giving rise to a new series of quantities which are mere linear measures of bolographic ordinates h_1, h_2, h_3, etc.

The process by which these ordinates can be transformed into thermal intensities, extrapolated to zero air mass and finally converted into the thermal magnitude E_0 is highly tedious, complex, and entails numerous corrections for errors, losses, etc. It is fully described in the various Annals of the Astrophysical Observatory. Since the invention of the pyranometer or "short method" of observing, Doctor Abbot has practically discarded the bolographic or "long method" for securing daily values of E_0 (but not for determining "function transmission curves"[4]) because errors of individual determination are so serious that reliance can be placed only upon group means of values thus found.

While the bolographic method is the only fundamental one for getting values of the solar constant at a single station, its errors nevertheless probably exceed 1 per cent or more if we fairly include the long train of secular and systematic errors of a semiconstant character. The only way to learn something definite about such errors is to maintain two or more *completely independent* sets of instruments in operation side by side for a whole year or more. This would permit simultaneous measurements at the duplicate stations, of the *same thermal energy* transmitted through the *same air mass*, and all differences in daily values could then be due to nothing but instrumental or within-the-observatory errors.

Pyranometry.—The pyranometer is an instrument which measures the brightness of the sky in a limited annular area around the sun. The process by which it is possible to get values of the solar constant from its use is entirely empirical and arbitrary. The method is described in Volume IV of the Annals of the Astrophysical Observatory, and its use requires both pyrheliometer and bolographic records as a basis. Sometimes several values of the solar constant can be secured in the same half day, giving a mean value of seemingly small error.

Whichever method of observing is followed, unavoidable variations in day-to-day values are necessarily present, due solely to errors. Wherefore, in order to preserve the analytical integrity of our final equations, and especially to recognize the highly important part which daily, weekly, and seasonal atmospheric states play in causing entirely fictitious variations in the solar constant, we shall introduce the total errors, X, Y, Z, due to all causes in the equation representing a final single value.

$$I_0 = \begin{cases} (A_0 - X)\, p_0 \text{ Pyrheliometer} \\ E_0 - Y \text{ Bolograph} \\ E_{wm} - Z \text{ Pyranometer} \end{cases} \qquad (8)$$

These are now the final rigorous relations between I_0, as the true solar intensity treated as a wholly independent variable, and the faulty measurements we may make of it by either or all of the instruments named. The equations are practically self-evident and axiomatic, but the detailed relations of the terms to direct observations have been set out in the preceding equations (1) to (7).

Gaussian distribution.—When we contemplate and talk about day-to-day solar variations our language is vague and indefinite until we indicate the nature of the *frequency distribution* of such variations. Direct observational evidence on this point is wanting; the total variation of the best *derived values* always conforms quite closely to the Gaussian distribution. The better, the more numerous, and the more homogeneous are the data, the closer is the conformity. Now, since the distribution of accidental errors is always approximately Gaussian, we have no choice from present evidence but to assume that *solar variations* also are Gaussian; otherwise, either there are no solar variations at all, or they are such a small part of the total variation, as to make no impression on the normal distribution which represents total errors.

Solar variations v. errors.—It is quite possible that changes of solar intensity as measured at the earth may occur every time a sun spot passes nearly centrally across the sun's disc, and some large temporary and infrequent changes may be caused in this way. However, these are a class of effects by themselves and must be so studied. On the other hand, years of observation show that over long periods day-to-day fluctuations, the relation of which to the sun is at least extremely doubtful, occur constantly, and that variations due to all possible causes have become smaller and smaller as the errors of measurement have been reduced. The fluctuations due to errors must always have a finite value. Hence the improvement in observational methods has now confined within very narrow limits the range of possible solar changes, which was formerly considerable.

It is, of course, wholly impossible to get daily values of X, Y, or Z, but we can always make numerous comparable observations and compute from these the standard deviation or other index of scatter due to all causes. Provided solar changes and errors are uncorrelated (i. e., σ_i not large or small according as σ_x is large or small), we can, from the well-known rules of least squares, write the equation expressing the relation of this *total variation* to variations caused by errors and by the sun as follows:

$$\sigma_t = \sqrt{\sigma_i^2 + \sigma_x^2}, \qquad (9)$$

in which the standard deviations σ are designated by subscripts which signify: t, the total variation due to all causes; i, the variation due to solar variability; and x, that due to errors of all kinds.

As long as day-to-day solar changes are no greater than the best modern observations show to be possible, our only source of real information about solar changes is to be found through some bona fide solution of equation (9). If solar changes are zero then the total changes are simply the total errors. And since the errors can never be zero, solar changes are only a part of the total changes.

The problem of two or more stations.—Simultaneous observations at two or more stations are so scanty that apparently no one has attempted any considerable analysis of such data. It seems well, however, to write out the statistical equations which can be employed. The data at each station furnish an equation of the type of (9), thus

$$\sigma_t = T_x = \sqrt{\sigma_i^2 + \sigma_x^2} \text{ for station } X \qquad (10)$$

$$\sigma_t = T_y = \sqrt{\sigma_i^2 + \sigma_y^2} \text{ for station } Y \qquad (11)$$

The subscripts x and y connote the variations due to errors pertaining to the stations X and Y, respectively. Each equation separately contains two unknowns and is therefore indeterminate. The two equations contain three unknowns and are still indeterminate. However, let us find the difference between simultaneous values

[4] MONTHLY WEATHER REVIEW, February, 1923, p. 74, and April, 1923, p. 188.

at the two stations and evaluate the total variation T_{xy} of such differences. Then we get,

$$T_{xy} = \sqrt{\sigma_x^2 + \sigma_y^2} \qquad (12)$$

Thus we secure three simultaneous equations with three unknowns, permitting *absolute* evaluation. However, the result will have little or no physical meaning unless the unknowns are entirely independent. There must be no secular or systematic fluctuations in the simultaneous values due to other causes than the sun. Annual periodicities in solar constant values, and their correlation with air transparency and other terrestrial conditions, will generally serve to vitiate the physical significance of the results drawn from the three simultaneous equations.

The mathematician recognizes, of course, that securing a seemingly rational and finite value of σ_1 in the solution of the three equations for a group of simultaneous observations is no proof of solar variability. Having *assumed* solar variability, a solution of the equations simply apportions to solar variation such part of the total variation as best satisfies the observations at the two stations under the assumed conditions. Some sets of observations may give imaginary roots, and it is obvious that errors of observation can be neither zero nor imaginary.

Solar variation can be shown by these equations only when the results are based on several groups of data from wholly independent stations. As pointed out above, equations of the type of (9) are valid only if σ_1 is unrelated to σ_x or σ_y in magnitude.

Possibilities of the variate difference.—If a, b, c, d ---- m, n are homogeneous consecutive values of any variant, then $b-a$, $c-b$, $d-c$ ---- $n-m$, and $a-n$ constitute the *complete* sequence of variate differences. This statistical datum seems to be capable of serving many useful purposes. Apparently its use has never been invoked in the critical analysis of solar radiation data.

Emphasis is placed upon taking the complete sequence of differences in-a-ring by adding to the consecutive differences usually taken, the difference between the first value and the last. This is literally a complete integration around a cycle of changes and affords important analytical advantages.

There are important similarities and important differences between the departures from the mean in a body of data and their statistical cousins the variate differences. The algebraic sums of the departures from the mean and variate differences in-a-ring are zero. The average departures from the mean without regard to sign, commonly called the mean deviation *md*, is wholly *independent* of the order of succession of the variant. The average sum of the variate difference disregarding signs is wholly *dependent* upon the order of succession. The natural order of succession may give a value of the mean variation, $\overline{V}$, quite different from a fortuitous order. If the order of succession is fortuitous and the distribution Gaussian, the following important relation holds:[5]

$$\frac{\overline{V}}{md} = \sqrt{2}$$

Just as we measure scatter or variability [illegible] mean square of the departures, so the scatter of [illegible]-to-day values of the solar constant can be measured by the quantity $\frac{\Sigma V^2}{n} = \overline{V^2}$, and at a single station we will have

$$\frac{\Sigma V^2}{n} - 2\frac{\Sigma X^2}{n} = \frac{\Delta I_o^2}{n}$$

[5] Marvin, C. F., MONTHLY WEATHER REVIEW, Sept. 1924, 52: 441. Woolard, E. G. MONTHLY WEATHER REVIEW, March 1925, 53: 107.

This equation is easily derived from any of the observational equations in (8) by forming the variate difference V and ΔI_o. In simplified nomenclature, using the superior bar to represent mean values we have

$$\overline{V^2} - 2\sigma_x^2 = \overline{\Delta I_o^2} \qquad (13)$$

Simultaneous observations at a second station, together with an equation based upon the difference between the values at the two stations gives

$$\overline{V_x^2} = \overline{\Delta I_o^2} + 2\sigma_x^2 \text{ Station } X \qquad (14)$$

$$\overline{V_y^2} = \overline{\Delta I_o^2} + 2\sigma_y^2 \text{ Station } Y \qquad (15)$$

$$\overline{T_{xy}^2} = \sigma_x^2 + \sigma_y \qquad (16)$$

in which the mean variations and errors for the respective stations are designated by the subscripts x and y.

Thus we have, by using departures from means in the one case and variate differences in the other, two different means of securing quantitative evaluations of the variations of solar intensity. As soon as two or more really independent stations supply observations of the solar constant as free as possible from annual periodicities and correlations with atmospheric and climatic features, we may hope to gather some worth-while evidence for or against day-to-day and other solar variations.

Observations at different air masses.—Equation (9) can be used in the analysis of observations of actual intensities at different air masses. Day-to-day variations at a single air mass can be ascribed to only three causes:

(1) Errors of observation X—never zero.
(2) Atmospheric depletion a—always changing.
(3) Solar changes—if they exist.

If a and I_o remain constant while air mass changes, the scatter due to depletion of incoming radiation is directly proportional to the air mass, m, and the total variation due to all causes is

$$\sigma_t = \sqrt{\sigma_x^2 + \sigma_1^2 + m^2\sigma_1^2} \qquad (17)$$

in which σ_1 = the variation at air mass 1 due solely to day-to-day changes in a. It must be understood that in this equation all changes due to failure of a or I_o to remain constant during observations are classed as errors and appear in σ_x. Since σ_1 is wholly independent of m, and since nothing is known as to how σ_x may vary, as it must, with m, equation (17) can be used to evaluate only σ_1^2 and $(\sigma_x^2 + \sigma_1^2.)$ and will be applied in this way later.

The analytical and other principles presented in the foregoing appear to be a sound and sufficient guide for the detailed analysis of the various groups of data. This will now be taken up.

II.—ANALYSIS OF PYRHELIOMETER READINGS AT CALAMA, CHILE, USING STANDARD DEVIATIONS [6]

The pyrheliometer is the fundamental and indispensable instrument for all measurements of solar intensities. Its errors are smallest, most certainly known, and most nearly constant of all the instruments employed. When standardized by comparison with an absolute or invariable normal, the pyrheliometer would be entirely sufficient by itself to secure values of the solar constant if the

[6] It is a pleasure to acknowledge the assistance rendered by the several members of the Weather Bureau staff who have so effectively cooperated during the preparation of the analyses presented in this paper.

radiation to be measured were monochromatic. The long train of mirrors, prisms, bolometers, galvanometers, pyranometers, and the elaborate procedure and empirical corrections entailed by their use are necessary solely to overcome the errors which polychromatic radiation introduces when the pyrheliometer alone is employed.

This limitation upon the pyrheliometer applies only to securing the *absolute* value of the solar constant. Day-to-day changes in those values, if they exist at all, *must appear in readings of the pyrheliometer*. The bolometer is simply an empirical analyzer whose function is solely to put the observed total intensities at different air masses in the form of spectral ordinates, h_1, h_2, h_3, etc., so that the Langley-Bouguer equation for extrapolation to zero air mass can be applied thereto. The analysis must not be allowed to add to or take from the total heat registered by the pyrheliometer.

The mass diagram Figure 1 contains a mine of information for the earnest student. Each dot individually is the logarithm, reduced to mean solar distance, of the observed intensity at the particular air mass represented by its abscissa. It is as nearly an errorless observational fact as the art of pyrheliometry, combined with conscientious observing under cloudless skies, permits. The dots falling on or near any vertical line represent observations at the same air mass at intervals of one or more whole days.[7] The variations in intensity such dots show are caused in part by small instrumental errors but chiefly by changes from one day to the next either in solar intensity I_0, or in air transparency a, or to both causes. At the extreme right, under conditions of low sun (air mass 5), the intensities are small, the air mass changes rapidly from minute to minute, and the errors are relatively larger than for high sun, that is for air masses between 1 and 1.5. Here intensities are high, air mass

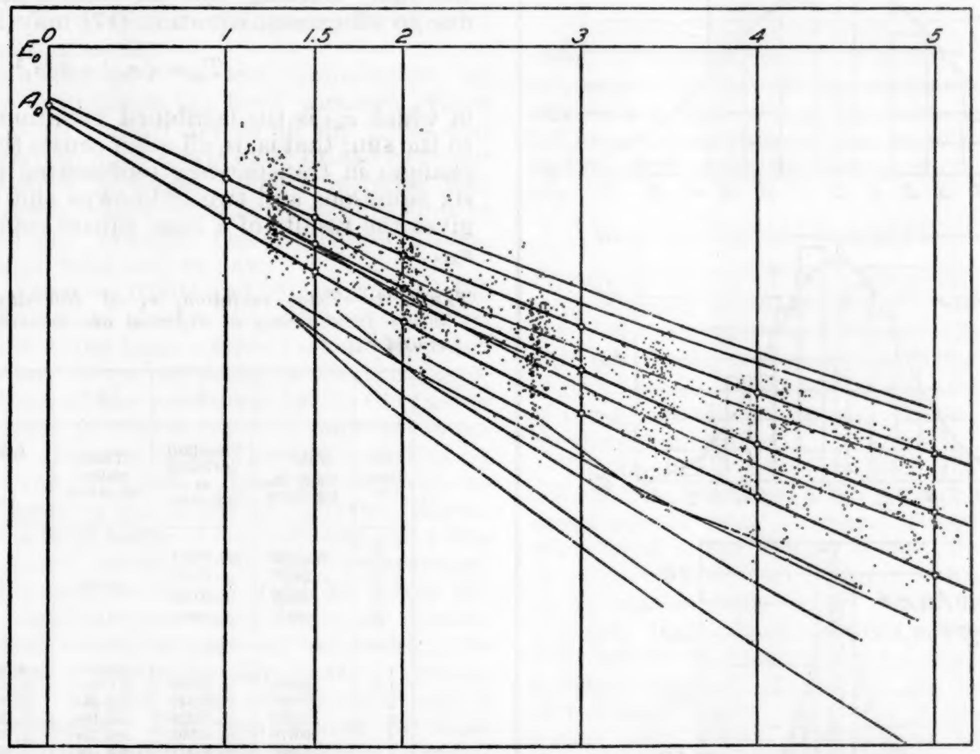


FIG. 1.—Mass diagram of 239 pyrheliometer readings at Calama, Chile. Tables 27 and 28, Annals Astrophysical Observatory, Vol. IV. A few broken lines join values for the same day. The annual mean values at air masses 1 to 5 are shown extrapolated by quadratic equation (7). Departures above and below the mean, $\pm\sigma_m$, for each air mass are similarly extrapolated. A few outlying dots in the upper part of the diagram represent observations at high-level stations other than Calama, and not included in this analysis

In a like manner the pyranometer also is an empirical device. It is used as a highly arbitrary substitute for the rigorous law of extrapolation to zero air mass. Obviously, it also can not be allowed to add to or take from the true amount of atmospheric depletion. Therefore, all *fluctuations* of solar constant shown by either or both of these empirical devices which can not be definitely shown to be already registered in the total heat or parent data secured by the pyrheliometer must at once be suspected as artificial and introduced by the empirical devices.

Recognizing the fundamental and basic nature of the original pyrheliometric observations, their analysis is therefore, our first objective.

The year as a unit of record.—A full year is the natural and only safe climatic interval to employ in the analysis of solar constant values which, experience shows, are permeated through and through with local and terrestrial atmospheric effects.

changes very little in several minutes, and the order of accuracy is generally higher. However, observations at any given air mass frequently show irregular changes of intensity from minute to minute, due either to variations of a or of I_0 or of both. From air mass 5 to air mass 1 the observations, individually nearly errorless, collectively are permeated with variations caused by the failure of a and I_0 to remain constant with the lapse of time between observations.

To analyze these more than 1,400 observations, the logs of intensities were assembled to give individual daily values of intensity at integral air masses 1.5, 2, 3, 4, and 5 for each of the 239 days, making a total of about 1,200 values. These were secured by a graphical interpolation between observations lying most nearly contiguous to the standard air mass required. The large scale of the

[7] This statement follows from the universal practice which for small air masses assumes that m=sec. z. If any error is involved in the application of this equation to observations at the same station on widely different days, seasons, etc., an additional cause for fluctuations in derived values of the solar constant of non-solar origin, is introduced.

diagrams permitted logs to be read to four significant figures. Unerring fidelity to the original observations was the main objective in this classification of the data, which was necessary to permit of the mass statistical studies we now present.

Solar constant and the scatter of parent data.—Since all observations on different days *at the same air mass* are nearly errorless we may choose any air mass as a standard of reference. Assuming that sky conditions permit, there are several advantages in favor of high sun, i. e., small air mass, conditions. The intensities are highest and air mass most nearly constant; accordingly errors are least. The effects of atmospheric extinction and depletion are least and the effects of changes of solar intensity greatest. For these reasons we have chosen for analysis the data for air mass 1.5, and figure 2 shows the frequency distribution of the original nearly errorless observed facts and what happens when daily observations are extrapolated to zero air mass by equation (6) and by the operations of the bolographic computations.

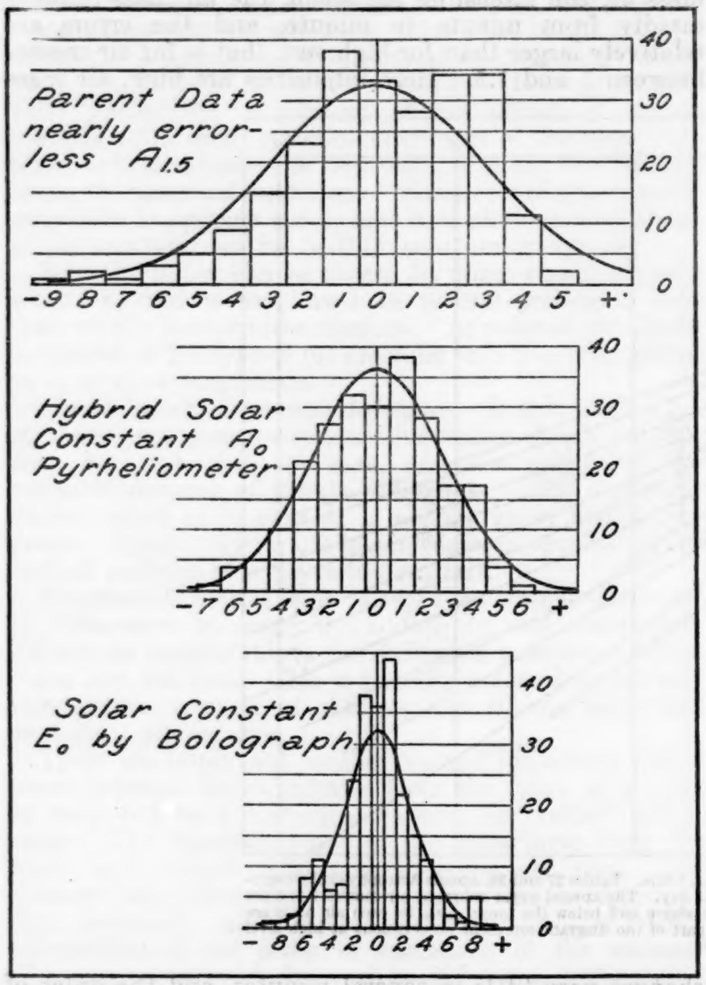


FIG. 2.—Diagram showing in comparison and contrast the frequency distribution of 239 daily values of the solar intensity: (1) The nearly errorless parent pyrheliometer values as observed at air mass 1.5; (2) the hybrid solar constant derived by straight-line extrapolation of the pyrheliometer observations to zero air mass; (3) the solar constant E_o derived by the bolographic method

The standard deviations, σ_t, for the three groups, $A_{1.5}$, A_o, and E_o are nearly in the order 3, 2, 1, respectively. There is actually nearly 80 per cent more scatter in the hybrid solar constant A_o than in the Langley bolographic value E_o derived from the same parent data, represented by $A_{1.5}$. Since the bolographic process necessarily introduces a whole family of errors and variations all its own, which are not in the parent observations at all, and since the bolograph can not exclude those variations which are in the parent data, due to failure of the sun and the transparency of the air to remain constant during observations at different air masses, we are compelled to explain the 80 per cent greater scatter of log A_o (± 0.01059 log unit) as compared with that of log E_o (± 0.00594 same unit) as caused by variations due to polychromatic effects. If our reasoning is sound and the above proportion chargeable to polychromatic effects at a station like Calama, Chile, is physically too large, as seems to be the case, then some question arises as to the validity of the bolographic operations. However, no conclusion can be reached until we have had opportunity to extend the same analysis to other bodies of independent data.

Equation (17) applied to scatter at different air masses.—Equation (17) serves to separate the scatter due to change in transparency from one day to another from the remaining scatter, which can be due only to errors and to the sun. Putting T_m = the total scatter at air mass m due to all causes, equation (17) may be written

$$T_m = \sqrt{\sigma_{x1}^2 + m^2\sigma_1^2} \tag{18}$$

in which σ_{x1} is the combined variation due to errors and to the sun; that is, to all other causes than the day-by-day changes in transparency represented by $m\sigma_1$. We have six equations and two unknowns and the following table gives the results of a least square computation of σ_1 and σ_{x1}.

TABLE 1.—*Total variation, σ_t of 239 day-to-day pyrheliometer values for Calama at different air masses, with calculations of σ_1 and σ_{x1}.*

	1	2	3	4	5
Air mass m	Mean [1] value $\overline{A}_m$ log units	Standard deviation σ_t log units	Theoretical, no errors	Least square values, equation (18) Log units $m\sigma_1$	σ_{x1}
0 $\overline{E}_o$	0.28862	±0.00594	$\sigma_t=\sigma_1$	0	±0.01304
$\overline{A}_o$	.24377	±.01059			
$\overline{A}_s$	.24336	±.00744			
$\overline{A}_q$	.25728	±.00388			
1	----------	----------	±1.41σ_1	±0.00640	Residuals.
1.5	.18076	±.01550	±1.80σ_1	±.00958	−0.0085
2	.15568	±.01842	±2.24σ_1	±.01277	−.0023
3	.11002	±.02525	±3.16σ_1	±.01916	+.0341
4	.06770	±.02905	±4.12σ_1	±.02554	+.0079
5	.02807	±.03377	±5.10σ_1	±.03193	−.0204

[1] Mean values are designated by a superior bar.

Explanation of Table 1.—Column 1 contains the mean value of the log A_m derived from the several classifications for computing σ_t. Only 4 place logs were used but the 5th place is retained in means.

Column 2 contains for air masses 1.5 to 5 the measure of total scatter due to all causes as obtained directly from nearly errorless observations over a climatic interval of one year. These values are the parent data from which all information must be derived.

The several values at air mass 0 are results derived by various methods devised to compensate for the losses of solar intensity caused by atmospheric depletion. At the same time, each method unavoidably introduces greater or lesser variations of its own, which are not present at all in the parent data. These values will be discussed later.

Column 3 represents what we ought to get from errorless data on the assumption that the total observed variations at air mass 1 are caused to an equal degree by the day-to-day changes in solar intensity and air transparency.

The very small effect of solar changes at air masses 4 and 5 shows how little significance such observations have in revealing solar fluctuations.

Columns 4 and 5 give the values of σ_1 and σ_{x1} derived from a least square application of equation (18) to the data in column 2. Changes in air conditions between observations are of course purely relative matters. Hence it is permissible to assume that observations at air mass 5 are standard; that is, that all changes between observations at different air masses occur *after* the observation at air mass 5. Consequently, observations at air mass 5 as a group are nearly errorless. If now no changes whatever had occurred on any day between observations and the solar intensity had also remained constant throughout the year, then the value $\sigma_1 = \pm 0.03377 \div 5 = \pm 0.00675$ is the amount of change we should have found at air mass 1. It is significant that the least square value $\sigma_1 = \pm 0.00640$ is almost identically the same. The latter value we regard as the most exact measure we can get, from the parent data, of the scatter due to the true changes in atmospheric transparency from day to day.

The other value derived from the computation, by least squares $\sigma_{x1} = \pm .01304$, is the total variation which we ought to get at air mass 0 due to all the errors and variations in the parent data *except those caused by variation due to atmospheric depletion*. Those included are: (x) instrumental errors combined with variations due to solar and atmospheric changes between observations, and (i) solar changes from day to day.

Although this value $\pm .01304$, which represents the total variation at air mass zero, is larger than any other, it is perfectly valid, being large simply because equation (18) (not by previous design but simply in effect) extrapolates to zero air mass *all* the variations due to the failure of the air and the sun to remain constant between observations. When an observer makes this extrapolation by eye he distributes the variations among the observations at different air masses as his judgment dictates. Equation (18) gives us a *large scatter at air mass zero and a true measure of day-to-day variations in air transparency*. The observer's judgment, on the contrary, by giving different weight to the observation at different air masses, results in individual values for zero air mass which are inaccurate (although showing smaller scatter) because associated with an erroneous value of the coefficient of atmospheric transmission. The combination of these circumstances produces considerable negative correlation, for, almost without exception the variations in the solar constant value show an inverse relation to those of the coefficient of atmospheric transmission.

As a basis for discussing the most important feature in the table, namely, the wide scatter of the four values for air mass 0 (column 2), these are assembled in Table 2, together with σ_{x1} from column 5.

TABLE 2.—*Standard deviation σ_t due to all causes at air mass zero by different methods*

Symbol	σ_t	Remarks
E_0	±.00594	Bolographically determined, includes all variations x and i in parent data and adds a family of errors of its own.
A_0	±.01059	Pyrheliometric values include all variations x and i in parent data and add errors due to extrapolation of polychromatic radiation by a straight line.
A_s	±.00744	Secured by taking half the difference between the intercepts at air mass zero of two least square straight lines fitted to points $\bar{A}_m + \sigma_m$ and $\bar{A}_m - \sigma_m$.
A_q	±.00388	Secured like A_s but the extrapolation to zero air mass effected by quadratic equation (7). See Fig. 1.
σ_{x1}	±.01304	Total variation due to errors and sun as evaluated by equation (18).

The wide difference and seeming contradiction between the values $\pm .00388$ and $\pm .01304$ are really consistent and easily interpreted. The value $\sigma_t = \pm .00388$ is a valid statistical datum of day-to-day variability, more free than any of the four others from the harmful variations due to unavoidable errors of various kinds. It is derived directly from the entire body of parent data without introducing appreciable errors of its own. It is the value we ought to secure if each day's observations could be extrapolated to zero air mass with no more error than applies to the mean values for the year, which are nearly free from the large errors affecting the extrapolated daily values.

The quadratic equations for the data $\bar{A}_m + \sigma_m$, $\bar{A}_m$ and $\bar{A}_m - \sigma_m$ designated by subscripts 1, 2, 3, are, respectively,

$$A_1 = 0.26217 - .0462m + .00122m^2$$
$$A_2 = 0.25728 - .0538m + .00158m^2$$
$$A_3 = 0.25442 - .0629m + .00218m^2$$

Quantitative result of analysis.—Using the minimum value of scatter found, $\pm .00388$, as least affected by terrestrial causes of fluctuations, and reducing the standard deviation σ to probable variation, we get the following mean value of the solar intensity for the year and the day-to-day fluctuation in calories and percentage, viz:

$$\bar{E}_0 = 1.9436 \ \pm (.0117 = 0.60\%)$$

For the purposes of the above conversion of units it is quite immaterial what value of the solar constant we use. We take the mean value for the year, $\bar{E}_0$, as probably nearest the true mean and find a percentage variation of only ± 0.60, which is just about the order of accuracy of the recent observations of the Smithsonian Institution by the pyranometer.

The reader should remember that the value $\pm .0117$ calories is a measure of the probable departure from the mean annual solar constant of any daily measurement when freed to the highest degree from all kinds of errors. It is derived directly from pyrheliometer observations at air masses from nearly 1 to over 5 on 239 days at Calama, Chile, from July 27, 1918, to July 24, 1919. This minimum value is only two-thirds as large as the average variation shown by the bolographic reduction of the same parent data and is equal to the scatter of recent high grade observations by the pyranometer. Considering the great difficulty in securing extreme accuracy in any daily value of the atmospheric depletion of incoming radiation, this small total probable departure may well be nothing but unavoidable error. Nevertheless, small as it is, we are still justified in assuming that a part of it is caused by day-to-day changes in solar intensity. To be fair to both sides of the question, let the total variation be equally apportioned to errors and to the sun. The share of possible solar variation then becomes $\pm .0117 \div \sqrt{2} = \pm .0083$ calories.

There is no definite statistical evidence as yet that any of the total observed variations have a solar origin, and the foregoing possible amount of variation *by assumption* approaches the irrational, because we have no assurance whatever that the total $\pm .0117$ is the irreducible minimum. When it is possible to secure by standardized pyrheliometers alone their nearly errorless observations at *n widely separated and independent stations*, we must inevitably cut down the above value σ_x in the ratio of 1 to $\sqrt{n}$. Otherwise we approach the absurdity that the errors of the Calama observations

are but a small fraction of the total variations found to be $\pm.0117$. It is quite in harmony with past experience to expect that the mean of only *three* stations making pyrheliometer readings as good as those at Calama will reduce this total to $\pm.0117 \div \sqrt{3} = \pm.0068$ calories, a *whole* variation which is now less than the *part* of the Calama variations assumed above to be of solar origin.

Here again final conclusions must be reserved until data from independent stations are available and until other studies now in progress are completed.

Annual periodicity in Calama solar constant values.—There seems to be no sufficient reason why there should be a twelve-month period in solar intensities. Especially is this true when such a period is correlated to a high degree with seasonal and annual states of the atmosphere induced by changes in vapor pressure, precipitable water, transparency, etc. The presence of such periods in values of the solar constant is prima facie evidence that there are present in those values important day-to-day errors of entirely terrestrial origin. No criticism or objection need be made to these relatively small errors when taken in connection with annual mean values of solar intensity, but the most serious objections are justified when it is insisted that the day-to-day variations in *derived daily solar constant values* should be accepted as fair representations of day-to-day and other short-time changes in *solar intensity*. The latter proposition is very far from having been proved. Doctor Abbot feels that his critics are too exacting and should not require impeccable observations. As one who has only praise, not criticism, to express for the splendid quality of Doctor Abbot's work as a whole, I want to make it clear that on my part at least, faulty observations are accepted as inevitable. What I desire is that every fault of the original observations be made clear, so that students may know with just what they are dealing. The great need is for a flawless interpretation of all the bits of evidence, whether for or against solar fluctuations.

The only way in which we can ever hope to get at the root of the matter is to bring into the foreground every known cause of fluctuations in the derived values. Under such conditions, no real solar variation could possibly escape detection and partial evaluation. Any other course implies a lack of confidence in the enormous power of modern statistical methods to reveal the secrets deeply hidden in large masses of homogeneous data.

Again, the point can not be too strongly emphasized that a whole year is the shortest climatic interval which can legitimately be employed in the analysis and adjustment of solar constant data. The atmospheric states of transparency, dustiness, water vapor content, convection, etc., have a regular cycle of their own completed only in the round of a full year, and these states exert such a direct and profound influence upon the values of the solar constant that it is futile to hope that a few months' observations are free from highly important systematic and semiconstant errors, or that empirical corrections, reductions, reduction factors, function values, etc., can be satisfactorily evaluated in less than a year if at all.

Figure 3 tells in such a graphic way its own story of the annual periodicities in the Calama observations that little explanation is required. The number of observations per month averaged 20 and were distributed as follows:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
17	20	15	26	25	17	12	25	18	24	22	18

The distribution leaves very little room for criticism as to the realness of the annual features shown by the monthly means.

Theoretically the extrapolation of daily observations to zero air mass is supposed and expected to faithfully *exclude* the effects of purely terrestrial and atmospheric states. The diagram shows at once to the eye, without correlation coefficients or other quantitative measurements that the theory and expectation are satisfied only in part. Actually, each terrestrial feature of annual periodicity, whether in transparency, water content of the air, or intensity for a given air mass, *is more or less faithfully extrapolated,* and is not excluded from solar constant values. Nevertheless, it is gratifying to point out that the monthly values of E_o for 1918 to 1920 at Calama are more nearly free from annual periodicity than any other group of annual values published either before or since. The details of this matter will be presented in Section V.

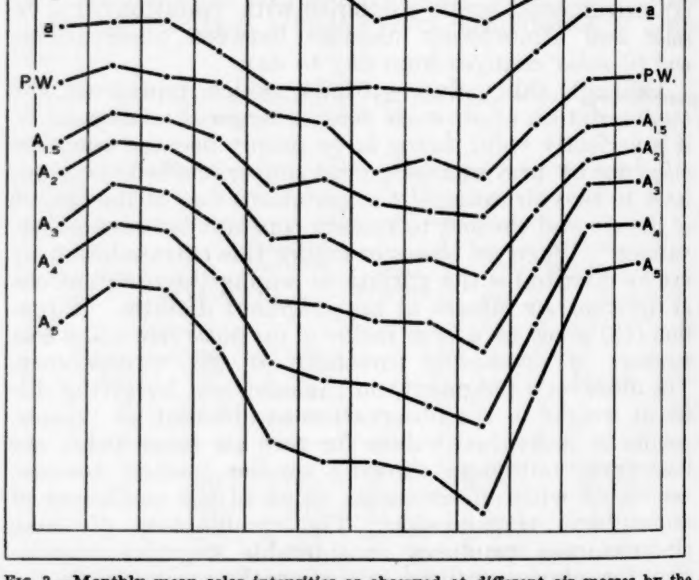


FIG. 3.—Monthly mean solar intensities as observed at different air masses by the pyrheliometer at Calama on 239 days, also values extrapolated to zero air mass, including values of air transparency *a* and atmospheric precipitable water P. W. (plot inverted), all showing correlation and 12-month periodicity

If we were seeking statistical evidence of the change of solar intensity from one month to the next, instead of from one day to the next, we could point to the systematic increase in the value of E_o culminating in December, with subsequent decline to a minimum in March. The December feature fairly satisfies the conditions of equation (18), but the relations of the companion feature of the March minimum to the parent data are entirely opposed to those prescribed in that equation.

The hypothesis of solar variation in this particular instance is further invalidated by the high negative correlation of E_o with the transparency and water content of the air. No one can say what the sequence of daily values of E_o would show if freed more completely from these sources of error.

III. ANALYSIS OF CALAMA DATA BY CORRELATIONS

The statistical device of the correlation coefficient must not be neglected in our search for the facts about day-to-day solar variations.

A graphical tabulation of the significance of such statistical indices derived from the analysis of observations passing progressively from assumed simple and more or less ideal conditions to actual conditions affected by errors, seems to be the most forceful way of presenting what is desired in this section. To aid those who may not be versed in the subject of correlations, this tabulation may be prefaced by a brief statement of a few fundamental principles.

Errorless observations of two quantities a and A, which are known to be in linear functional relation, will show perfect correlation, ± 1.00, provided no other cause than a can produce changes in the values of A. If a second cause, I, wholly independent of a and A, can also cause observed values of A to change, and if I is just as potent as a in producing changes in A, the correlation coefficient between a and A will be $\sqrt{(\frac{1}{2})^2+(\frac{1}{2})^2}=.71$. If I dominates, then the correlation between a and A will be less than 0.71, according to the relative potency of I and a. If a dominates, the correlation will be higher than 0.71. A correlation of 0.91 for errorless values of a and A would imply that a is nine times as potent as I in causing changes of A.

Errors of measurement are of course causes of variation and produce definite effects on correlation coefficients. The potency of entirely fortuitous errors, if large, compared with that of a physical cause like a, may change a ± 1.00 correlation between errorless values of a and A to a small coefficient of, say $\pm .10$, more or less. If the number of values in correlation is sufficiently large, the sign of a true correlation will not be changed by errors, but if the number is small, or if the errors are partly systematic, their presence may not only reduce the size of the real correlation but may even change the sign. Such effects of errors will be the same, regardless of whether one or several causes in combination produce the correlations.

Before reading what follows, Table 3, on page 297, should be carefully examined.

Discussion of Case V of Table 3.—This case deals with the actual pyrheliometer and other observations made at Calama July, 1918, to July, 1919. See Figure 1 and the discussion of scatter values already given in Section II.

In considering correlations between derived solar constant values it must not be forgotten that every cause of variation is known and that, excepting purely fortuitous errors, the causes are united in known functional relations, mostly linear—all of which makes the results presented in Table 4 of the highest significance.

The essential features of Table 4 appear in the first four lines which should be compared with corresponding data in Cases I, II, and III.

TABLE 4.—*Correlations between logs of observed pyrheliometer values adjusted to standard air masses 1.5 to 5, and values of solar constants E_0, A_0 and fair transparency a, also precipitable water P. W.*

		a	E_0	A_0	$A_{1.5}$	A_2	A_3	A_4	A_5
1	*p. w.*	−0.59	−0.33	−0.56	−0.74	−0.79	−0.80	−0.69	−0.55
2	a	--------	−.50	−.25	+.49	+.53	+.64	+.69	+.51
3	E_0	--------	--------	+.69	+.48	+.56	+.45	+.55	−.18
4	A_0	--------	--------	--------	+.61	+.67	+.61	+.53	+.65
5	$A_{1.5}$	--------	--------	--------	--------	+.88	+.82	+.72	+.51
6	A_2	--------	--------	--------	--------	--------	+.84	+.73	+.48
7	A_3	--------	--------	--------	--------	--------	--------	+.70	+.40
8	A_4	--------	--------	--------	--------	--------	--------	--------	+.59

The high negative correlation of E_0 and A_0 with a and *p. w.* is evidence of the grave fault in all the solar constant values, which almost without exception show a considerable negative correlation with atmospheric transmission coefficients. Zero correlation should be found, because real day-to-day solar variations can not be related in any direct way to atmospheric transparency or water vapor. The correlation E_0 and a, -0.50, as compared with -0.25 for A_0 and a, does not necessarily signify that A_0 values are better than E_0, because, as pointed out in connection with Figure 2, the scatter of A_0 is 80 per cent greater than that of E_0. We may therefore infer that fortuitous variations in A_0 due to polychromatic effects, which are absent from E_0, reduce the correlation of A_0 and a below what it would otherwise be.

The remaining correlations in the first two lines are entirely rational but would be much higher except for fortuitous variations due to errors.

Lines 3 and 4 of the table tell a very definite story. Errorless values of E_0 and A_0 should show a high correlation unless the fortuitous differences between them due to polychromatic radiation, as distinguished from all other causes of error, are themselves inherently large. This is a matter deserving fuller investigation. The table shows a coefficient of $+0.69$, which interpreted by Dines' [8] law means that only 48 per cent of day-to-day variation in these two values of the solar constant, which are derived from the same parent data, occur in synchronism.

Still greater interest attaches to the correlations with intensities at the different air masses, which will now be discussed.

Sun constant from day to day.—All variations in E_0 and A_0, except those in A_0 due to polychromatic radiation will now be fortuitous errors and therefore uncorrelated with intensities at different air masses. The slightly larger coefficients in line 4 over those in line 3 may be caused by a functional relation between variations due to polychromatic radiation and change in transparency of the air from day to day.

Sun variable; no errors.—The coefficient E_0 and $A_{1.5}$ $+.48$ may be interpreted to mean that day-to-day changes in air transparency cause three times as much variation at air mass 1.5 as that caused by the sun; that is, the sun causes about one-fourth the whole. On this basis, the correlation a and $A_{1.5}$, line 2, should be 0.88 $=\sqrt{1-(48)^2}$ instead of 0.49, and all the remaining coefficients in lines 2, 3 and 4 should be radically different from what they are. There is no escape from the conclusion that the assumption of day-to-day solar variation as great as one-fourth the total observed at air mass 1.5 is entirely invalidated by the mutual correlations of Table 4.

Of the evidence in lines 2, 3, and 4 the most rational interpretation is, that since all the observations are permeated with errors the greater part of these errors are faithfully extrapolated to zero air mass and there appear as variations in the values of the solar constants E_0 and A_0.

The correlations in column A_5 are all noticeably low. We are inclined to regard this as wholly due to the accumulation of considerable relative errors in the data in this part of our original values. The errors are not inherent in the observations separately, but, owing to atmospheric changes, observations at different air masses are erroneous relative to each other. In the practical work of extrapolating, the observer habitually

[8] Meteorological Magazine, Feb., 1921.

gives more weight to the data from smaller air masses, thus making the relative errors large at air mass 5 and producing lower coefficients of correlation than should be the case.

The correlations between intensities observed *within* the atmosphere are quite rational, but seemingly low. This is to be expected when we remember that a value for each individual air mass is nearly errorless in itself, but when compared with the value for another air mass on the same day the relative errors due to atmospheric changes (which often take place in only a few minutes) become serious and cut down correlation coefficients to relatively low values.

Weather Bureau pyrheliometer observations at Washington, D. C—Dr. H. H. Kimball has kindly assembled for me the logs of intensities and values of *a* for observations on a total of 105 of the clearest days possible for Washington between the dates December 17, 1914, and June 26, 1925. These readings range by half air mass intervals from 1.5 to 5 and were read from a smooth curve run through numerous observations by means of a spline, a method which served also to give the extrapolation to zero air mass. The value of *a* was deduced from the slope of a *straight* line generally passing through the observations nearest air masses 1.5 and 4. The exhaustive analysis of these observations is not yet completed, but it is noteworthy that the correlation of A_0 with *a* came out exactly zero, as we like to have it.

Among the 105 days there were 59 on which values of E_0 were found by the Smithsonian Institution at Mount Wilson or one other of its stations. The correlation between these few values was +0.13. While the number of variants and the size of the coefficient is very small, the latter signifying an efficacy of only $\frac{1}{60}$, it has the right sign for a very small solar variation. Here again final conclusions must await confirmation from other bodies of data.

The foregoing Sections II and III are submitted both as an example of how a body of homogeneous observations of the pyrheliometer alone may be analyzed and interpreted in terms of day-to-day changes in solar intensity and also to show how weak the statistical evidence still is for any appreciable changes of solar intensity.

In closing these sections I wish especially to make it clear that I disclaim any intimation that the quantity A_0 is anything more than the name I have given it connotes, namely, *a hybrid solar constant*. I do insist, however, *that the pyrheliometer measurements, including values of A_0, contain within themselves all the observational evidence we have of day-to-day or other short-period variations in solar intensity*. The bolograph and pyranometer, either separately or in combination, are powerless to take from or add to the total intensity registered by the pyrheliometer, *except in the form of an errorless extrapolation of the observed value to zero air mass*. The fallibility of human measurements is known to be such that errorless extrapolation to zero air mass is impossible, therefore arbitrary empirical instruments like the bolograph and pyranometer only add their own inherent error to those of the parent data. Therefore, again, any variations in the extrapolated data that can not be absolutely shown to reside in the parent data and to be not due to error in those data, must be ascribed to errors of the subsidiary instruments and methods. *Such variations can not possibly be ascribed to the sun unless and until they can be identified in the parent data.*

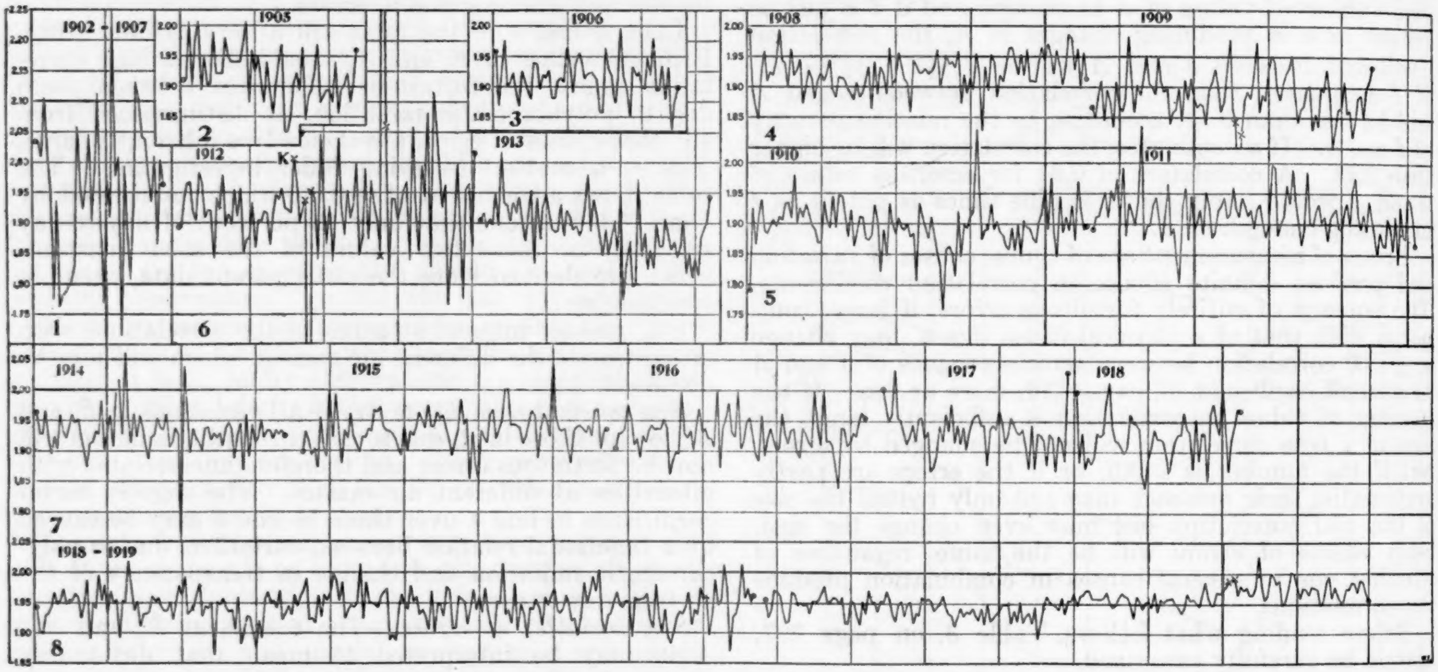


FIG. 4.—Diagram of nearly 2,000 observed values of solar constant as determined by the Smithsonian Institution from the beginning of observations in 1902 to the end of 1919 at stations Washington, D. C., Mount Wilson, Calif., and Calama, Chile

IV. GENERAL EXAMINATION OF THE VARIABILITY OF ALL VALUES OF THE SOLAR CONSTANT BY BOLOGRAPH AND PYRANOMETER

A general conception of the whole question of variability of solar constant values is most readily gained by a careful inspection of Figures 4 and 5, which show in consecutive order practically all observations published from 1902 to November, 1924. The reader is asked to follow closely in Figure 4 the groups of data numbered consecutively 1, 2, 3—8, noticing especially the great increase in range of values in 1912, when the explosive volcanic eruption of Mount Katmai caused a notable increase in the scatter of values due to dust in the high

TABLE 3.—ANALYSIS OF THE EFFECTS ON DERIVED VALUES OF THE SOLAR CONSTANT EXERTED BY DIFFERENT INDEPENDENT CAUSES

(The relations between measures of scatter, and the mutual correlations among all the variables, are shown in the columns headed "scatter" and "correlations". Diagrams showing extrapolation to zero air mass represent the mathematical relations for any beam of monochromatic radiation rigorously, and for polychromatic radiation approximately.)

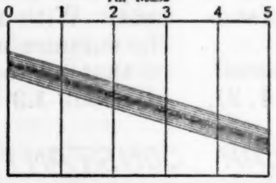
Assumed conditions (Case No. — Solar — Terrestrial) | **Effects as reflected in observations** (Extrapolation to zero air mass — Scatter — Correlations, all positive except as otherwise indicated)

Case I

Solar: All changes are caused by sun alone. Scatter $= \sigma_i$

Terrestrial: Conditions and instruments ideal. No errors or changes of any kind. Transparency of air constant from hour to hour and day to day indefinitely. Transmission coefficient = a

Extrapolation to zero air mass:



Scatter: Scatter of observed values at all air masses identical and same as in sun $= \sigma_i$

Correlations:

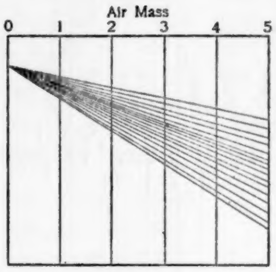
	E_0	A_0	A_1	A_2	A_3	A_4	A_5
a		0	0	0	0	0	0
A_0			1.00	1.00	1.00	1.00	1.00
A_1				1.00	1.00	1.00	1.00
A_2					1.00	1.00	1.00
A_3						1.00	1.00
A_4							1.00

Case II

Solar: Sun and I_0, E_0 A_0 absolutely constant.

Terrestrial: No errors of any kind. Conditions still ideal as in I, except that while air transmission a remains constant during one day's observations a changes irregularly from one day to the next.

Extrapolation to zero air mass:



Scatter: The a lines of extrapolation focus to an exact point at zero air mass. Scatter there equals zero; elsewhere as below:

Air mass	Scatter
0	0
1	σ_1
2	$2\sigma_1$
3	$3\sigma_1$
4	$4\sigma_1$
5	$5\sigma_1$

Correlations:

	E_0	A_0	A_1	A_2	A_3	A_4	A_5
a		0	1.00	1.00	1.00	1.00	1.00
A_0			0	0	0	0	0
A_1				1.00	1.00	1.00	1.00
A_2					1.00	1.00	1.00
A_3						1.00	1.00
A_4							1.00

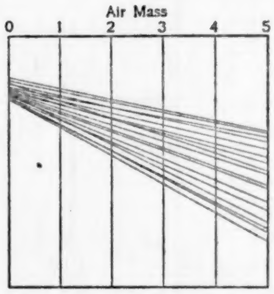
Case III

Solar: Cases I and II combined, two independent and equal causes of variation. Sun constant during observations, but changes intensity irregularly from day to day. Scatter $= \sigma_i$

Terrestrial: No errors or other causes of variation. except transparency, which remains constant during observations but changes irregularly from day to day.

Scatter $= \sigma_1$

Extrapolation to zero air mass:



Scatter: Total variation now reflects changes due to both the sun and day to day changes in transparency. By the law of propagation of variations, scatter becomes $\sigma_m = \sqrt{\sigma_i^2 + (m\sigma_1)^2}$

Air mass	Scatter $\sigma_i = \sigma_1$
0	σ_i
1	$1.41\,\sigma_1$
2	$2.24\,\sigma_1$
3	$3.16\,\sigma_1$
4	$4.12\,\sigma_1$
5	$5.10\,\sigma_1$

Correlations:

	E_0	A_0	A_1	A_2	A_3	A_4	A_5
a	0	0	.77*	.91	.96	.98	.99
A_0			.63*	.42	.28	.20	.14
A_1				.88	.82	.80	.79
A_2					.95	.93	.92
A_3						.98	.97
A_4							.99

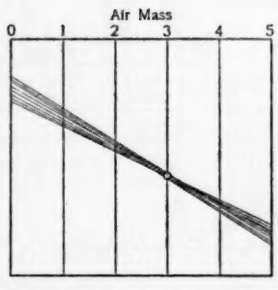
*See remarks.

Case IV

Solar: Solar conditions constant in every particular.

Terrestrial: All variations due solely to errors, caused, first, by fallibility of observer and his instruments. <u>These are the errors within the observatory</u>. Second, the failure of the transparency of the air to remain constant during low and high sun observations. This is the atmospheric cause of error. To simplify representation, assume the transparency of the air to be the same day after day at the time observations are made at air mass 3, and that before and after this time the transparency changes each day in an irregular but natural way by hazings and clearings.

Extrapolation to zero air mass:



Scatter: The values secured by extrapolation to zero air mass and the scatter in Case IV can hardly be distinguished from those allowed as possible for Case I, representing pure solar variation. At other air masses the scatter increases above and below air mass 3. The little circle at air mass 3 represents the possible error of the pyrheliometer alone. Every observation under the assumed conditions falls within the circle.

Correlations:

	E_0	A_0	A_1	A_2	A_3	A_4	A_5
a	−.50±	−.50	±0	±0	±0	±0	±0
E_0		±0	±0	±0	±0	±0	±0
A_0			±0	±0	±0	±0	±0
A_1				±0	±0	±0	±0
A_2					±0	±0	±0
A_3						±0	±0
A_4							±0

Case V

This is the actual natural problem. Four entirely independent causes, three of which are in strictly functional and linear relations, produce variations in observations and results: namely, (1) <u>air mass</u>, the only cause under control; (2) <u>change in air transparency</u> from one day to the next; (3) <u>possible solar changes</u> from day to day; (4) <u>all errors in combination</u>, classing change in transparency and solar intensity during observations as a source of error. Errors produce variations which are not in functional relations, but often of semisystematic character, with seasonal and annual features. The detailed discussion of the actual data will be made in the following text.

REMARKS FOR TABLE

CASE I.—Scatter at all air masses must be the same. Transparency and solar constant must be uncorrelated because the transparency of the earth's air cannot cause solar changes, and solar changes do not in any direct and instantaneous way change atmospheric transparency. Correlations between all intensities = 1.00.

CASE II.—No cause for variation except change in transparency from day to day. Scatter directly proportional to air mass for errorless observations. Correlations possible only between intensities at different air masses, and all = 1.00.

CASE III.—Spontaneous and unrelated changes in sun and atmospheric transparency now the sole cause of variation of intensities at the different air masses and all are measured without error. The diagram and table of correlations represent (but not to scale) 101 errorless observations satisfying the conditions assumed, namely, (1) that the sun spontaneously undergoes variations about equal to the total variations observed at Calama from July, 1918, to July, 1919, and (2) that the transparency likewise spontaneously changes from day to day to such degree that intensities at air mass 1 are statistically identical with those assumed for the sun, <u>but wholly uncorrelated thereto</u>. The 101 pairs of variants A_0 and a are drawn from a bowl of Gaussian numbers. The "errorless observations" are the intensities at air masses 1 to 5 derived by a <u>reverse</u> extrapolation calculated with rigorous accuracy on a Marchant Calculator. Correlations by Clough's method. The two drawings of fortuitous numbers should have shown equal correlations, $1 \div \sqrt{2} = .71$. The slightly different values, column A_1, .77 and .63, mean that the random drawings failed slightly to conform to theory.

CASE IV.—All day to day variations in this case are caused solely by the aggregate of all errors, the effects and evaluation of which is, of course, the moot question of this whole subject. To make any adequate evaluation of such errors, with their annual and seasonal characteristics, requires access to the original observational records comprising one or more <u>full</u> years, so as to include all kinds of atmospheric states.

Case IV assumes that the sun is constant and that at the time the air mass is 3 the air transparency is exactly the same on each day, but that the transparency changes in a natural way during the period covered by observations at other air masses. The peculiar assumption is only to aid in visualizing the effects of errors. The one value at air mass 3 is almost errorless, being affected only by the small error of the pyrheliometer. The straight lines of extrapolation to zero air mass will cross above and below A_3 so as to best fit this and the other values for the day, resulting in the diagram as shown. Any doubt that conditions like these cause large variations in the derived values of the solar constant is dispelled by a critical acquaintance with actual daily observations and such mass diagrams of observations as Fig. 1 for Calama for the year July, 1918, to July, 1919. The scatter of values at air mass zero is drawn to the same scale as in Cases I and III, to represent very nearly the observed variations at Calama during 1918-19, as if all of them were due to errors alone. Obviously, only a part of the observed variations can be ascribed to the sun, because errors can never be zero.

In the absence of an actual evaluation of X we cannot assign numerical values to the correlations, except that the well-known negative correlation between E_0 or A_0 and a will certainly be −.50, more or less. The other correlations, being caused more or less accidentally (waiving a possible habitual tendency of the air to haze up instead of clear up), will have small positive and negative values designated by the symbol ± 0.

strata. Smaller scatter attended the subsidence of this dust during the next two years, followed by a fairly steady state of the record during the five years until 1918, when the new station at Calama, Chile, began observations under improved atmospheric conditions. We notice here in the first half of Group 8 an appreciable drop in the scatter. Finally, in 1919 (latter half of Group 8) a new type of observing by means of the pyranometer led to a notable further drop in scatter.

Passing to Figure 5, Group 8 of Figure 1 is repeated, with later values *on an enlarged vertical scale* (lines 1, 2), result, expressed as a percentage of the average value of the solar constant which has nearly the same value, 1.94 calories per square centimeter per minute, for all groups.[9]

On this basis Figure 6 shows the scatter of the several groups of data shown in Figures 4 and 5.

Prior to the opening of the station at Calama, the very best observations showed a scatter of about 1 per cent. With the exception of the observations made in the summer of 1908 at Mount Wilson, the diagram tells us that up to 1911 the best observations show a scatter of about 1.3 per cent. Then came 1912 when Mount

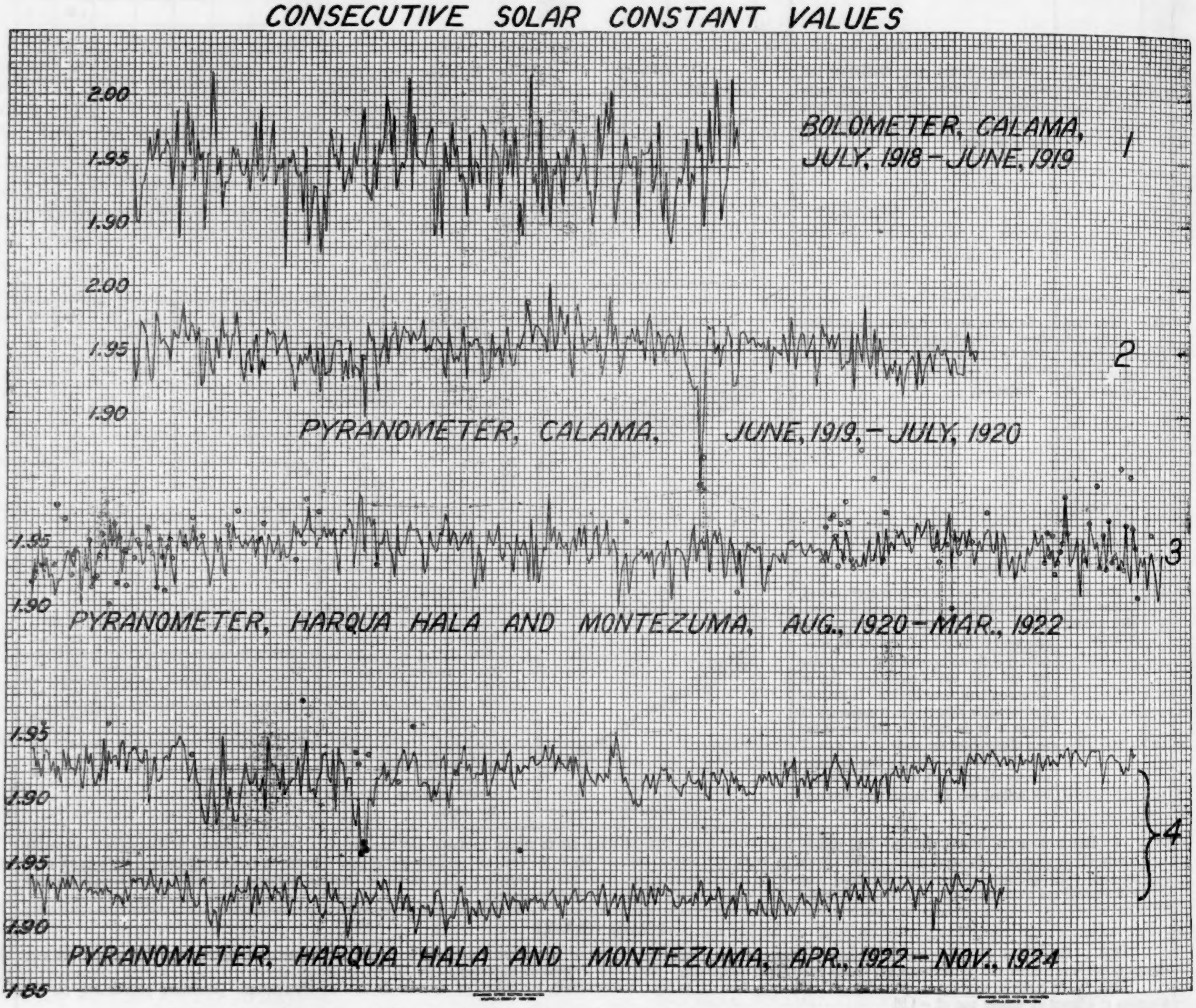


FIG. 5.—Consecutive values of the solar constant as observed at stations in South America from July, 1918, to November, 1924

followed by the sequence of all published values to November, 1924, on the same scale. All pyranometer readings show smaller scatter than bolographic observations.

The unaided mind is incapable of appraising the real significance and relative importance of these different amounts of variability in the different groups of data, but, happily, the science of statistics gives us several accurate measures of the varying degrees of scatter which such observations show.

The index of scatter best suited to present purposes seems to be the *probable error or variation* of a single daily

Katmai threw great quantities of dust into the high strata of the atmosphere, increased general atmospheric turbidity and caused the scatter to increase to fully double the best previous value, or over 2 per cent. This large

[9] To remove any possible uncertainty concerning this measure of scatter we give the formula for its derivation.

$$\epsilon = \frac{.6745}{E_o}\sqrt{\frac{\Sigma v^2}{n-1}} = \frac{.6745}{E_o}\sigma \text{ when } n \text{ is large}$$

Σv^2 is the sum of the squares of the departures from E_o, the average value of the solar constant for a group. The standard deviation, $\sigma = \sqrt{\frac{\Sigma v^2}{n}}$, can often be used with convenience and accuracy.

index of variability gave place slowly in the four following years to low values, just over 1 per cent, for the years 1915 and 1916. The index of scatter then increased again to fully 1.3 per cent in the year 1918. Shall we say this increase was caused by greater solar activity or rather due simply to poor observing conditions at Mt. Wilson and wholly unavoidable errors of measurements? The latter conclusion is the correct one, *because the station at Calama had been put in operation and its observations for this same summer of 1918 show a decidedly smaller index of scatter and variability than ever before obtained.* Finally, even this small scatter of less than 1 per cent was cut very nearly in half, in the middle of the following summer, by the introduction of the pyranometer method of making observations. Happily, we have bolographic or long method observations for the first half of 1919, showing a scatter of just under 1 per cent, whereas the values by the new method for the latter half of 1919 show a scatter of only 0.52 per cent. Of course this change in scatter can not be explained by a sudden subsidence in solar variability coincident with the beginning of observations by the pyranometer, but is best explained as a reduction in the errors of measurement.

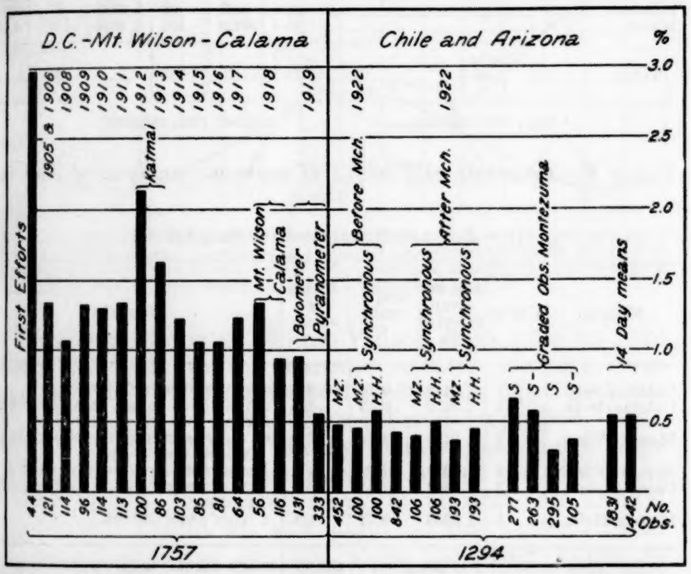


FIG. 6.—Probable percentage variation, due to all causes, of daily values of the solar constant, showing the values by groups from the older, more variable to the modern, less variable

Summing up the one outstanding result obtained by the assiduous program carried out up to 1919, it is this: *Atmospheric turbidity is the main cause of a large scatter in solar constant values, which scatter by the best stations and best methods was reduced to only 0.52 per cent by the close of 1919.*

Passing to the second part of Figure 6, representing the probable variation of several groups of data obtained at Montezuma and Harqua Hala during the years 1920 to 1924, we find in general a still further reduction in scatter. Thus 452 solar constant values spread over a period of nearly 20 months prior to April 1, 1922, show a scatter of only 0.49 of 1 per cent. Again, a group of 100 synchronous observations at the two stations within this period shows a scatter of 0.45 per cent for Montezuma and 0.59 per cent at Harqua Hala. Then, again, a large group of 824 highly comparable observations at both stations made after March, 1922, and covering a period of 32 months, gave a scatter of only 0.41 of 1 per cent. In these results we see the scatter going lower and lower as observations increase in number and methods are still further refined. During this same period we have two groups of synchronous observations at the two stations. One with 106 observations which show a scatter of 0.40 and 0.50 per cent, respectively. The other group comprises 193 observations with a scatter of 0.38 and 0.44 per cent. The smaller scatter in each case applies to Montezuma. It is hardly necessary to ask why this difference in scatter at the two stations. It is obvious that the variability of the sun can never be greater at one station than at another, especially for stations on nearly the same geographic meridian. It is equally obvious, however, that errors of measurement may differ greatly at the two stations, and that solar variability can not be greater than the least variability at the best station. That is, solar variability can not have been greater during the 32 months over which the 299 synchronous observations were spread than the two small values of scatter, 0.40 and 0.38 per cent at Montezuma.

We can not claim that even now these small measures of scatter represent mostly solar variability, because that involves the impossible assumption that each of the 299 observations was nearly 100 per cent perfect. There is no rational interpretation of the mute evidence presented by this great body of data except to recognize that both the large and the small day-to-day fluctuations in the value of the solar constant have always been largely, if not wholly, due to variations in the unavoidable errors of observation resulting chiefly from the ever-changing turbidity of the atmosphere.

A further evidence of the extreme smallness of possible solar variability may be added.

Doctor Abbott has classed each of the observations as made, into grades designated S, $S-$, $U+$, and U, meaning *satisfactory*, *nearly satisfactory*, *rather unsatisfactory*, and *unsatisfactory*. Though we do not believe that the grading of observations by arbitrary methods is likely to be wholly satisfactory, the results are accepted at face value and from an analysis of four groups we find as follows:

No. 1 comprises 277 S observations, covering about 34 months after August 3, 1920, and therefore includes the secular changes and drop in 1922, which doubtless causes the scatter, 0.66 per cent, to be larger than it would otherwise be.

No. 2 comprises 263 comparable $S-$ observations, covering the 52 months beginning August 1920 and showing the smaller scatter of 0.62 per cent. We should expect the observations graded as less satisfactory to show a larger scatter, while the actual result is just the reverse. Of course this is only one group of results.

No. 3 comprises 295 S observations, covering a period of about 18 months, beginning June 1, 1923. The Montezuma station was working very uniformly during all this period and observations of some kind were obtained almost every day. These 295 values show a scatter of only 0.30 per cent. Think of it: Over a total period of about 18 months, less than one-third of one per cent for all causes of variation!

Group No. 4 comprises 105 $S-$ observations, all interspersed among the S observations, and shows a scatter of 0.38 per cent.

We see from all the foregoing that the better our observations become, the smaller and smaller becomes the total variation due to all causes, and hence increasingly smaller must be the part which can be truly ascribed to solar changes.

Suppose real day-to-day changes of solar intensity of consequential magnitude actually occur. These can be statistically measured and represented by the symbol σ_l and such variations are related to errors of observation by our basic equation

$$\sigma_t = \sqrt{\sigma_l^2 + \sigma_x^2} \qquad (9)$$

We must recognize the inexorable consequences which flow from equation (9). Observations for more than 20 years have been giving us values of σ_t which have been growing smaller and smaller as better instruments, better methods, and better observing stations have been employed. Over all this period the day-to-day solar fluctuations σ_l if existent at all in consequential magnitude, have stood as an obstacle to diminution in the value σ_t. That is, σ_l is the irreducible minimum which σ_t approaches asymptotically as σ_x becomes zero. With σ_x still of finite value we have reached a low value of σ_t for the general run of recent observations of about ± 0.50 per cent more or less. This is now the total daily variation which we are required to apportion between errors and solar changes by means of equations (10), (11), (12). Before doing this we will first examine the whole body of data for annual periodicity.

V.—THE 12-MONTH PERIOD IN SOLAR CONSTANT VALUES FOR NORTHERN AND SOUTHERN HEMISPHERES

In this section will be shown the serious extent to which even the monthly mean values of the solar constant are systematically impressed with annual features associated with summer and winter states of the atmosphere. If monthly mean values, often based on observations for a period of several years, are subject to systematic terrestrial influences, how much more serious must be the everchanging atmospheric effects upon single daily determinations.

This analysis embraces practically all observations from 1905 to 1924. The 246 bolographic observations at Calama for the year July, 1918, to July, 1919, prove to be the best observations ever made for a single year, either before or since; that is, as a group they are most free from annual periodicity. Unfortunately, *frequent* daily bolographic observations terminated with the introduction of the pyranometer, beginning July, 1919. However, a total of 70 determinations of E_0 were secured by the pure [10] bolographic method during the year July, 1919, to 1920. These 70 observations are fairly well distributed through all the months, averaging from 2 to 9 days per month, and appear to be of a high quality though limited in number; therefore I have combined all observations in both years into mean monthly values. Whether by accident or not these 316 daily values as a group show decidedly the smallest systematic seasonal effects of all the groups of data, large or small, yet examined. It is significant that the observations were secured by the pure bolographic method at a single station.

[10] The adjective *pure* is used occasionally to allude to bolographic observations carried out rigorously in accord with Langley's basic idea, giving a result designated E_0. A correction for water vapor was applied to all such results at Mount Wilson, giving a supposed superior value designated E'_0. These values show a greater annual period than any others.

TABLE 5.—*Monthly mean values of the solar constant at various times and stations from 1905 to November 1924*

	x	From 1905 to 1920					From July, 1919, to November, 1924			
		Mount Wilson, Calif. (omitting Katmai, years 1912 and 1913), after June, 1912			Bolograph Calama, July, 1918, to July, 1919		Pyranometer			
							Calama, July, 1919, to July, 1924		Harqua Hala, October, 1920, to October, 1924	
		Number months or years	E_0	E'_0	Number days	W. M.	Number days	W. M.	Number days	W. M.
April	0	----	----	----	35	1.9483	110	1.9310	68	1.9252
May	1	4	1.9132	1.9348	32	1.9414	85	1.9316	90	1.9312
June	2	11	1.9225	1.9459	25	1.9519	96	1.9276	88	1.9222
July	3	13	1.9159	1.9435	13	1.9350	99	1.9366	43	[a]1.9247
August	4	13	1.9160	1.9446	35	1.9539	96	1.9334	28	[b]1.9277
September	5	13	1.9139	1.9375	25	1.9416	90	1.9390	68	1.9240
October	6	11	1.9145	1.9344	30	1.9374	88	1.9398	76	1.9348
November	7	4	1.9080	1.9310	27	1.9395	93	1.9420	65	1.9378
December	8	----	----	----	27	1.9558	79	1.9392	45	1.9378
January	9	----	----	----	22	1.9430	77	1.9454	71	1.9388
February	10	----	----	----	22	1.9465	62	1.9376	67	1.9328
March	11	----	----	----	23	1.9429	105	1.9324	55	1.9262
Total	----	*Months* 69	----	----	316	----	1,080	----	764	----

[a] July, 1923, missing. [b] August, 1923, missing.

TABLE 6.—*Constants and results of harmonic analysis of data in Table 5*

[$y = E_0 + c \cos(\theta - \varphi)$ Epoch of origin Apr. 15]

Station	Curve	Annual mean calories E_0	Amplitude c	Phase constant φ [a]	Remarks
Calama, 18-20	1	1.9448	0.0016	0.916	316 pure bolographic values.
Calama, 18-19	1	1.9452	.0042	.851	246 of above values, curve in broken line.
Mount Wilson	2	1.9123	.0058	.249	69 months of summer observations, May to November.
Mount Wilson	4	1.9335	.0109	.271	Parent data identical with curve 2.
Calama, 19-24	3	1.9363	.0061	.616	Pyranometer data over 5 years, 1919 to 1924.
Harqua Hala	5	1.9308	.0072	.658	4 years' observations.

[a] The phase constant φ is not given in the customary angular units but in a number representing the fractional part of the length of the period, thus easily fixing the phase position of the maximum. With the origin at April 15 the maximum for phase constant $0.916 = 12 \times 0.916 = 11$ months after April 15, viz, March 15. Similarly, $360° \times 0.916 = 329.°76$ angular units.

The monthly and general annual means upon which Figure 7 is based comprise such a large body of representative data that final values are tabulated for permanent reference in Table 5. We also give in Table 6 for reference purposes the constants of the harmonic analysis of the data in Table 5. These tables and diagrams present in highly concentrated form the testimony of fully 3,000 daily observations covering a period of work of nearly 20 years. Each monthly value we employ is, with rare exceptions, the mean of many daily values. Moreover, our final results do not depend in any material way upon any particular monthly value. The striking harmony and consistency in the results (Harqua Hala excepted) are the combined testimony of the entire mass of homogeneous statistical numbers.

Discussion of Figure 7.—The sequence of monthly means in No. 1 shows large variations above and below the annual mean, but the amplitude of the least square sine curve, continuous line, is so small in relation to its obviously large probable error that the mathematical

result should be interpreted as no annual period at all; that is, these monthly mean values of the solar constant on the whole are, as they should be, practically free from systematic terrestrial effects identified with the march of the seasons.

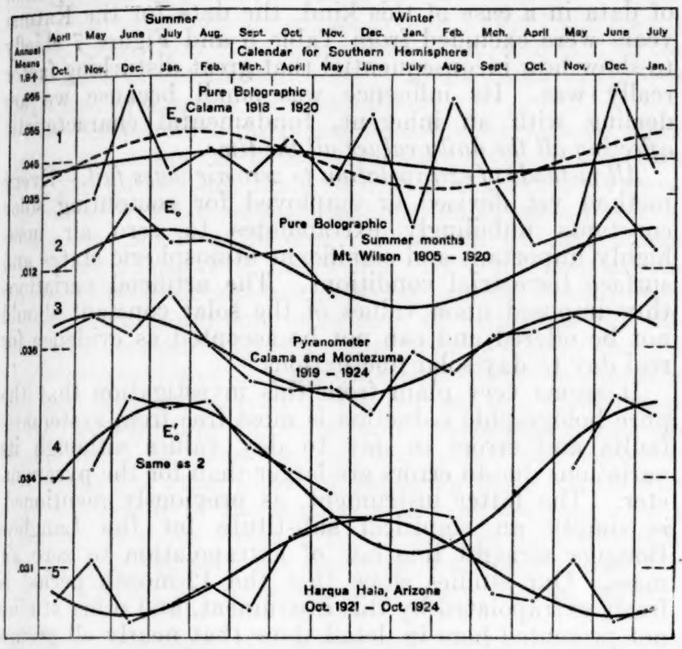


FIG. 7.—Monthly mean values of the solar constant in a sequence of 16 months in order to show fully the annual periodicity as a summer and winter terrestrial effect. The calendar for the Southern Hemisphere is shifted 6 months, to bring like seasons in both hemispheres into the same vertical lines. All scales same as at 1.

The observations at Mount Wilson from 1905 to 1920 were made only in the summer months, usually from June to October, but extended to include May in 1906, 1908, 1910 and 1912, and November during 1908, 1909, 1910, 1911, and 1913. The systematic seasonal change affecting the monthly means really stares the observant student in the face, and suggests at once an annual periodicity. Doubt on this point in the writer's mind was wholly removed in 1923 when the observations at Calama, Montezuma, and Harqua Hala from July, 1918 to September, 1922, were published.[11]

Since observations at Mount Wilson for the many missing months of the past years can never be supplied, no valid objection can be made to invoking least square methods to pass the best sine curve we can through the seven months' observations available. Curves 2 and 4 show the monthly mean values and the normal annual march for the two values E_0 from pure bolographic reductions and E'_0 a supposed superior value derived from E_0 by the application of a correction for atmospheric water vapor.

We regard even this one analysis of the meager data available in the case as a gratifying success; especially when it is so completely confirmed by the highly satisfactory fit of the sine curves to Calama, Montezuma, and Harqua Hala data, based on strong monthly mean values for every month of the year.

Katmai dust.—The doubtful values secured at Mount Wilson during the years 1912 and 1913 have been wholly omitted from the results shown in Figure 7. However, we have computed the sine curves, using all the data regardless of Katmai dust, with no very consequential difference of any kind. That is, the phases of the curves are hardly changed at all, and the amplitude of E_0 was increased from 0.0058 to 0.0069, and of E'_0 from 0.0108 0.0122. Doctor Abbot also objects[12] to my use of *all the Mount Wilson data* because it covers only one epoch of sunspot minimum, while there are two epochs of maximum. Therefore, we strike out all data for the year of strong sunspot maximum, 1917, and we still get the same period, with phases practically identical, amplitudes changed for E_0 from 0.0059 to 0.0055 and for E'_0 0.0109 to 0.0092. Thus the data refute the criticism.

It is difficult either to understand or to take seriously the following words by Doctor Abbot in answer to the evidences for the 12-month periodicity:[13] "I will not say there was absolutely nothing of the kind in Mount Wilson observations, but I regard it as nearly or quite nonexistent in later work. He [Marvin] has mistaken a real 11-month periodicity in recent years for a 12-month periodicity. Mr. Clayton discovered the 11-month periodicity over a year ago and reported it to me."

First, the period "is nearly or quite nonexistent. In the next sentence "it is a real 11-month periodicity." Is the period nonexistent, or is Marvin or Clayton mistaken about its length? It will take a lot of statistical evidence to prove "a real 11-month periodicity," whether evanescent or permanent, in solar constant values. When the length of the period has been proven to be, not 12 months, but 11, it will take another large mass of statistical evidence to prove that the periodicity is of solar rather than terrestrial origin. The case seems to stand in this way: Hardly denying that the Mount Wilson solar constant values show a 12-month periodicity, Doctor Abbot says that recent values show a real 11-month periodicity discovered by Clayton. Marvin insists that the real length of the period is 12 months, due to summer and winter atmospheric effects and submits the testimony of fully 3,000 daily values in proof and quantitative evaluation thereof.

Returning to the propriety of computing a 12-month periodicity from data for only 7 consecutive months, I want to say that we have no hope of securing an accurate evaluation of its constants. The existence of the period is the major present question. The results we give speak for themselves, truthfully representing all the data available. The features found are wholly in accord with like results for other stations making continuous observations over the entire year.

Incidentally, it must be emphasized that the fitting of a sine curve is the only correct method of getting the proper mean value of periodic data when values for a considerable part of the period are missing.

One of the noteworthy features about the Mount Wilson data (curves 2 and 4) is that the amplitude of the supposed inferior values of the solar constant E_0 is smaller than for later values (curves 3 and 5), and is but little over half the amplitude for the values of E'_0 which are supposed to be superior and are derived from the same parent data. The correction for water vapor applied to give E'_0 can hardly be considered as justified.

Curve 3 is noteworthy because it is based on pyranometer observations only, designated W. M. in the Smithsonian publications. Observations averaged 18 daily values per month for an unbroken period of 60 months, a total of 1,080 daily values. The fit of the sine curve must be regarded as highly satisfactory.

[11] MONTHLY WEATHER REVIEW, February, p. 71, and April, 1923, p. 188; Annual Period."

[12] Abbot, C. G., Solar variation and forecasting, Smithsonian Miscellaneous Collections, vol. 77, No. 5, pp. 11-12.

[13] Solar variation and forecasting, loc. cit., p. 9.

The foregoing remarks apply also to curve 5 based on 4 years pyranometer observations at Harqua Hala, with a total of 764 daily values.

What is the striking lesson the diagram as a whole teaches? Very clearly it is, that almost without exception monthly mean values of the solar constant exhibit a very definite annual period, unfailingly associated with summer and winter states of the atmosphere. The reader must remember that when stations in the Northern and Southern Hemispheres are being compared, there is an absolute time interval of six months between the values in any vertical line or band of the diagram. The sun, therefore, can have no part in causing the almost perfect synchronism which the eye catches at once, including the equally striking exception apparent in curve 5. All these effects are due to the one state common to all observations wherever and whenever made, namely, summer and winter atmospheric conditions: high solar constants with summer conditions, low constants with winter conditions. The clash and inconsistency in the trend of the monthly means as observed at Harqua Hala, as compared with the trend at its sister station, Mount Wilson, only 250 miles to the west, is complete and physically irrational. There is no lack of annual period in the monthly means at Harqua Hala. The smooth sine curve fits the observations with entire satisfaction. The summer and winter effect is all there. The inconsistency lies in the fact that it is the summer and winter atmospheric states at Montezuma in the Southern Hemisphere that influence the summer and winter values of the solar constant at Harqua Hala in the Northern Hemisphere. The explanation of this anomalous result is found in the following quotation from the annual report of the Astrophysical Observatory for 1924 (p. 105):

> As soon as we began to receive daily telegrams from both stations occasional fairly wide disagreements of individual days commanded attention. We felt it necessary, in studying the causes of such disagreements, to revise again entirely the systems of little corrections to solar-constant values which have to be made to allow for the haziness and humidity of our atmosphere. This revision could be made with more advantage because much additional data had meanwhile accumulated. * * *
>
> A new method of determining these corrections has been devised, which eliminates satisfactorily the influence of the solar changes which have occurred. Hitherto this matter of solar change superposed upon the small terrestrial sources of error which we desire to eliminate has been very embarrassing. Of course, if one could wait many years before proceeding to evaluate the terrestrial effects, the solar changes, being independent or but loosely connected with local terrestrial ones, would be eliminated in the mean of a mass of observations. We can, indeed, after several years more of observing, finally proceed in this way. But wishing to make immediate use of our results a new method of procedure has fortunately occurred to us which permits us to avoid the interference of solar changes altogether. The details will be published soon.

The method of making these corrections is described in the pamphlet on Solar Variations and Forecasting (p. 14). The method may seem to have been entirely valid in principle at the start, but the sequel of its actual application proves that it is clearly erroneous in its effects and we are reluctantly forced to take the position that *the provisional values of the solar constant for Harqua Hala as published in volume 77, No. 3, Smithsonian Miscellaneous Collections, can not be accepted as independent of those for Montezuma, and that the two values are correlated in an entirely artificial way.*

It seems to the writer futile to try to contest the overwhelming evidence in support of a 12-month period in the published values of the solar constant. Our analysis uses all the data available. The periodicity is present in the old as well as in the latest values. The amplitudes and phases are entirely comparable and consistent and can not be altered to any consequential extent by any valid selection or rejection of particular data. Only extraordinary reasons justify selection or rejection of data in a case of this kind; the data for the Katmai years were excluded from Table 5 and Figure 7 chiefly to show how inconsequential that great disturbing factor really was. Its influence was small because we are dealing with an inherent, fundamental characteristic *affecting all the daily values all the time.*

All methods of extrapolation to zero air mass fail.—Every method yet devised or employed for computing solar constants unfailingly extrapolates to zero air mass highly important and significant atmospheric states and surface terrestrial conditions. The artificial variations thus imposed upon values of the solar constant should not be offered and can not be accepted as evidence for real day to day solar fluctuations.

It seems very plain from this investigation that the pure bolographic reduction is most free from systematic faults and errors in day to day values although its variations due to errors are larger than for the pyranometer. The latter instrument, as previously mentioned, is simply an empirical substitute for the Langley-Bouguer straight line law of extrapolation to zero air mass. Our studies show that the 12-month period is freely extrapolated by this instrument, and other studies not presented here in detail show that nearly all groups of pyranometer values plot in decidedly skew forms of frequency distribution. This skewness is conspicuously a characteristic of *all surface readings of intensities,* especially at the higher air masses. It is clearly evident in the parent data (fig. 2), even for air mass only 1.5. The origin of this skewness is terrestrial, and therefore should not be extrapolated to zero air mass.

It is easy to see what would have happened had the telegraphic Harqua Hala observations been *rigorously independent* of those coming in from Montezuma. Assuming equality in other respects, daily telegraphic values would have seemed to agree nicely in the spring and autumn seasons, only to show wide systematic discrepancies during the summer and winter seasons. Obviously, the mean of independent daily values from the two stations, despite wide occasional differences, would tend to be nearly or entirely free from *an annual period.* I do not mean to imply that the actual original observations would show the above results, because it is not at all likely that the two stations and equipments are alike in other respects. It is quite certain that not only the equipment but the atmospheres at the two stations exert quite different effects upon daily values.

In the face of all the evidence we have presented to show the real nature of fluctuations in solar constant values it is a serious error of interpretation of original observations to insist that any of the published values of the solar constant fairly represent day-to-day changes in solar intensity.

The only course the writer can advocate is to see if it is not possible, as seems to be the case, to so modify the present methods of extrapolation to zero air mass as to mostly remove the existing serious objections. This of course is possible only to those having free access to original and unpublished observational data. Several promising possibilities seem to be opened up in the examples of analysis we have given.

VI. SOLAR VARIATIONS COMPUTED FROM OBSERVATIONS AT INDEPENDENT STATIONS

Disregarding a small constant difference between mean solar constants from groups of same-day observations at Montezuma and Harqua Hala, also the artificial correlation previously mentioned, we give in Table 7 the results of the application of equations (10), (11), and (12) to the evaluation of the station errors σ_x Montezuma, σ_y Harqua Hala and σ_i possible solar variability.

For comparative purposes the 399 observations made on the same days at both stations are divided into three groups representing more or less homogeneous values. A limited number of simultaneous bolographic observations were made at Mount Wilson and Calama during the years 1918, 1919, and 1920. By combining all the values into one group, being careful to preserve the lowest possible minimum sum of squares of variations and differences, by excluding effects due to large secular changes between years and to scale differences between stations, we get the results given in the bottom line of values in Table 7 indicating a possible solar variation of 0.55 per cent, which is from two to four times the variation shown by the other data. Comparing these results with the magnitude of the station errors we see that σ_i is a function of those errors, a fact which, as pointed out in Section I, invalidates the assumption that equations (10), (11), and (12) are three simultaneous equations between three independent unknowns. The results in Table 7, therefore, must be interpreted to mean that either solar variation is nonexistent or is relatively so small that it can not be disentangled from the irregular larger variations in daily values due to errors of observation.

TABLE 7.—*Calculation of solar variations from synchronous observations at Harqua Hala or Mount Wilson, designated by subscript x and at Calama or Montezuma, designated by subscript y.*

Date	Number of observations	Solar constant E_o		Total variation T			Calculated values			$\frac{0.6745\sigma_i}{E_o}$
		$\overline{E}_x$	$\overline{E}_y$	T_x	T_y	T_{xy}	σ_x	σ_y	σ_i	
										Per cent
Oct. 4, 1920, to Mar. 31, 1922	100	1.9460	1.9467	0.0129	0.0171	0.0176	0.0096	0.0148	0.0086	0.30
Apr. 1, 1922, to July 1, 1923	106	1.9168	1.9210	.0115	.0143	.0173	.0107	.0136	.0043	.15
Aug. 1, 1923, to Nov. 30, 1924	193	1.9251	1.9231	.0108	.0139	.0156	.0091	.0126	.0058	.20
July 27, 1918, to Sept. 6, 1920	66	1.9457	1.9417	.0301	.0241	.0314	.0256	.0174	.0158	.55

VII. CONCLUSION

Final definitive evidence, especially in quantitative measures, can not be secured from observations at a single station with only one set of observing instruments. .Much could be learned from check observations by wholly independent equipments maintained side by side, and it is hoped such check determinations can be secured at some station to be established in the future.

A considerable number of synchronous observations have been secured from stations in pairs, as Bassour and Mount Wilson, the latter and Calama, including Calama and Montezuma with Harqua Hala. Unfortunately, because of volcanic dust and other untoward circumstances, these synchronous values are so much affected by important accidental and systematic terrestrial and artificial causes as to more or less invalidate the evidence which these observations might show of a small possible variation, which can be entertained as real only when confirmed by future *independent* observations at other stations.

It is indicated in the text that pyrheliometer readings alone are nearly errorless values from which real solar variability can be proven and evaluated with considerable accuracy, especially if observations are secured from uniformly standardized instruments observed at several wholly independent stations in the arid regions of the earth and over as great a range of elevation as possible.

The International Commission for Solar Radiation has this subject under consideration, and the writer hopes its actions may lead to progress in this important field of geophysical science.

The presentation in this paper is offered as an example, so to speak—a preliminary survey and study. I expect to extend the investigation to many other observations thus far examined not at all or only in the most superficial way.

SMITHSONIAN SOLAR-CONSTANT VALUES

By HERBERT H. KIMBALL

[Washington, Sept. 1, 1925]

SYNOPSIS

This paper considers briefly the magnitude of errors in solar constant determinations arising from errors in the fundamental pyrheliometric readings and in their extrapolation to zero atmosphere.

The degree of correlation between solar constant determinations made nearly simultaneously at Montezuma, Chile, and Harqua Hala, Ariz., leads to the conclusion that only an insignificant part of their day-to-day variations can be attributed to some such common cause as solar variability.

INTRODUCTION

A critical study of the work during the past 20 years of Doctor Abbot and his associates in connection with determinations of the value of the solar constant leads one to a profound respect for the skill, energy, and devotion to science that is evident throughout. It is not a simple matter to obtain from measurements of solar radiation intensity made at the bottom of the sea of air the intensity of that radiation before it enters our atmosphere. This is what they have done, however, and with such precision that the published mean value of their determinations, 1.94 gram-calories per minute per square centimeter, is almost universally accepted, although this value is necessarily subject to a probable error that as yet can hardly be evaluated. That Doctor Abbot and his associates seem to recognize this is indicated by their statement that after all possible care in the standardization and intercomparison of instruments employed at Montezuma and Harqua Hala it was necessary to add a little more than 1 per cent to the solar constant determinations made at the latter station to bring them into accord with those at the former station.[1]

[1] Abbot, C. G., and Colleagues. Values of the solar constant, 1920-1922. MONTHLY WEATHER REVIEW February 1923, 51: 71-81. (See especially p. 74.)

ERRORS IN PYRHELIOMETRIC READINGS

When, however, we consider the day-to-day variation in the solar constant values, questions arise as to the extent to which these represent unavoidable errors of observation and reduction and to what extent they represent solar variability.

Some data bearing upon this question are available. For example, at the basis of all solar constant determinations are the pyrheliometric readings, and the means of series of comparative readings between different pyrheliometers given in the Annals of the Astrophysical Observatory, volume 4, pages 94–95, show an average variation in the mean ratio of the different series of a little more than one-half of 1 per cent. Or, stated in another way, the probable error in the ratio of any one of 37 series of comparative readings is ± 0.42 per cent.

For Montezuma, Doctor Abbot computes the probable error of a series of readings with one pyrheliometer of the improved silver disk type to be only ± 0.2 per cent; and since at that station two pyrheliometers are read in connection with each solar constant determination, he estimates the error of the determination due to inaccuracy in the pyrheliometric readings [2] to be only

$$\sqrt{\frac{(0.20)^2}{2}} = 0.14 \text{ per cent.}$$

This degree of accuracy can not be claimed for earlier determinations, where only one pyrheliometer, and that one of an earlier and less accurate type, was read.

In a recent publication [3] he computes the probable error of a solar constant determination at a single station to be ± 0.0065 gr. cal. per min. per cm², or ± 0.335 per cent; while for the mean of the determinations at two stations the probable error is given as ± 0.0046 gr. cal., or ± 0.237 per cent.

Assuming that Abbot's method of determining the probable error is correct in this case, it leads to the surprising result that the portion of the probable error attributable to errors in pyrheliometric readings outweighs that due to all other sources combined, both instrumental and atmospheric. In this connection it may be pointed out that Abbot's method of computing the probable error of solar constant values from the "average daily difference, Harqua Hala—Montezuma," is applicable only if the determinations at the two stations are entirely independent of one another.

The above does not include possible constant or secular errors in the pyrheliometric scale. It is inevitable that inaccuracies in the fundamental pyrheliometric readings will be carried into the day-to-day values of the solar constant, and will form a material part of the apparent day-to-day variations in the solar constant values.

ERRORS IN EXTRAPOLATION TO ZERO AIR MASS

We next have to consider the difficulty of extrapolating the pyrheliometric readings to zero air mass, or correcting for loss of intensity of radiation by absorption and scattering in its passage through the atmosphere. Doctor Abbot and his associates accomplish this by computing the atmospheric transmission for monochromatic radiation of about 40 different wave lengths from spectro-bolometric measurements, or by a secondary process based on spectro-bolometric measurements of the precipitable water in the atmosphere and pyranometer measurements of the brightness of the sky around the sun. Neither of these processes can give results that are absolutely correct. Without discussing the causes that lead to errors we have only to examine the individual determinations at the two stations Montezuma and Harqua Hala to see that this is so.[4]

In Figure 1 I have selected for this examination the solar constant values obtained on December 15, 1920, and June 9, September 27, October 3, October 7, November 21, December 2, and December 9, 1921.[5] These are days on which at the two stations at least six determinations of the value of the solar constant were obtained, and were given a rating of S or $S-$ (satisfactory or nearly satisfactory). They may be taken as typical of days so rated. Under each date the first row of values is for Harqua Hala, the second for Montezuma. Open circles indicate the individual determinations, closed circles the weighted mean value for each station and crosses the means for each day derived from the determinations at both stations. The probable error of the individual determinations on different dates varies between $\pm 0.23\%$ and $\pm 0.74\%$.

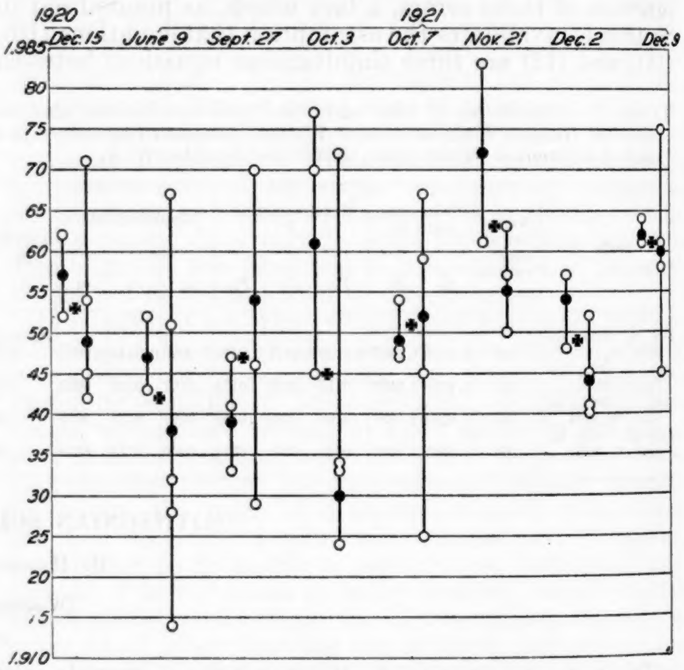


FIG. 1.—Individual, and mean values of solar constant determinations at Harqua Hala, Ariz., and Montezuma, Chile, on selected dates

We note the method of determining the solar constant value for a given day. The observations for each station are weighted in accordance with their reliability in the judgment of the observer and the computer, and from these weighted values the station mean is found. The mean of these two station means gives the adopted value for the day. It will be noted that on these eight particular days the difference between the extreme daily means is from 1.942 to 1.963, or 0.021 gr. cal., while the difference between the extremes of station means is from 1.930 to 1.972, or just twice as much.

[2] Annals of the Astrophysical Observatory, v. 4, pp. 162 and 166.

[3] Solar variation and forecasting. Smithsonian Misc. Coll., vol. 77, no. 5, 1925.

[4] Abbot, C. G., and Colleagues. Provisional solar constant Values, August, 1920, to November, 1924. Smithsonian Misc. Coll. vol. 77, No. 3, Feb., 1925.

[5] See Table 8, MONTHLY WEATHER REVIEW, February, 1923, 51:78-81.

CORRELATION BETWEEN DETERMINATIONS AT TWO STATIONS

There are 398 days between October, 1920, and November, 1924, inclusive on which solar constant values obtained at both Montezuma and Harqua Hala were considered good enough to be used in obtaining the mean solar constant value for the day. These values have been divided into three groups, as follows:

October, 1920, to March, 1922, inclusive, with 99 determinations at each station; April, 1922 to July, 1923, inclusive, with 106 determinations at each station; August, 1923, to November, 1924, inclusive, with 193 determinations at each station. It will be noted that the grouping has been made in such a way as to throw into the first group most of the secular variation that appears in the solar constant values during this time, and especially during the early months of 1922.

In Figures 2 and 3 the data represent values of the solar constant as determined at the two stations on the same day. The abscissa of a dot gives the value of the Montezuma determination; the ordinate, the value of the Harqua Hala determination. Figure 2 includes all the 99 pairs of values of the first group except two in which the Harqua Hala values, 2.021 and 2.000, fall beyond the upper limit of the ordinate scale of the figure. These values, with the corresponding values for Montezuma, 1.954 and 1.968, respectively, were included in the computation of the correlation coefficient between the solar constant determinations at the two stations, and this coefficient was found to be $+0.341 \pm 0.060$. Figure 3

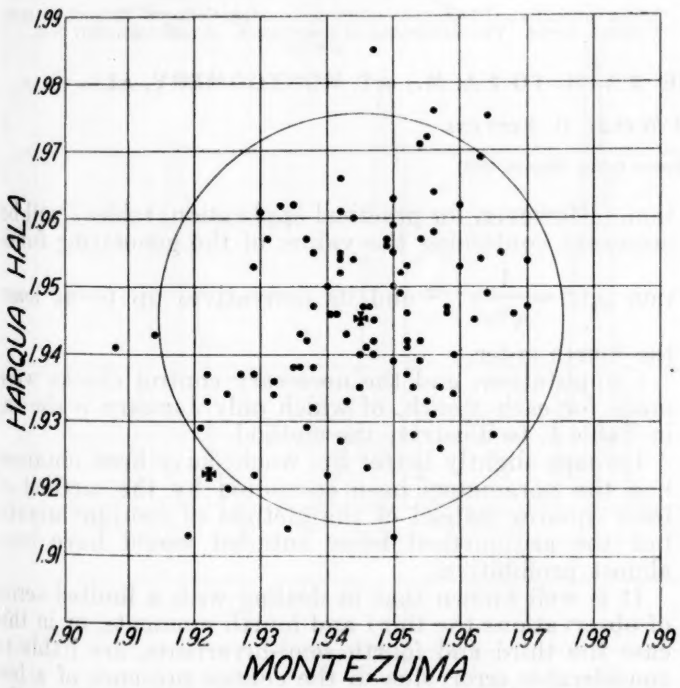


FIG. 2.—Values of the solar constant determined at Harqua Hala, Ariz., and Montezuma, Chile, on the same date, between October, 1920, and March, 1922, inclusive

includes all the 299 values of the second and third groups. The correlation coefficient for the second group is $+0.18 \pm 0.063$, and for the third group $+0.17 \pm 0.045$.

We have two methods of determining the significance of these correlation coefficients, as follows:

(1) It is generally agreed that before a correlation coefficient can begin to have significance it must exceed its probable error four fold.[6] Therefore, the coefficients for groups 2 and 3 have little or no significance, and that for Group 1 may have significance.

(2) Whipple[7] has shown that the degree of relationship between two variables is measured, not by the correlation coefficient, but by its square. This gives about 0.12 for the degree of relationship between Montezuma and Harqua Hala solar constant values of the first group. Therefore, of their standard deviations which are ± 0.013

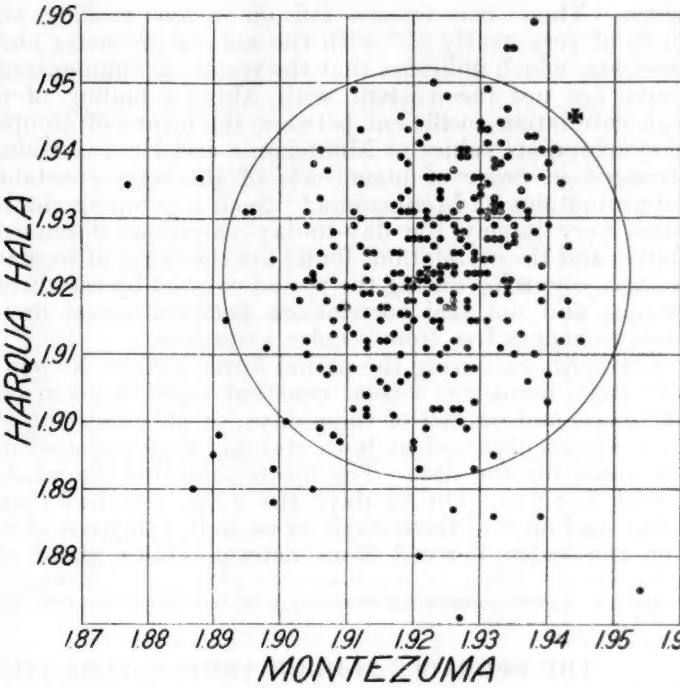


FIG. 3.—Values of the solar constant determined at Harqua Hala, Ariz., and Montezuma, Chile, on the same date, between April, 1922, and November, 1924, inclusive

and ± 0.017 gr. cal., respectively, only about ± 0.002 gr. cal. can be attributed to some such common influence as solar variability. Similarly, the extreme range of values in this group is for Harqua Hala from 2.021 to 1.913, or 0.118 gr. cal., and for Montezuma from 1.970 to 1.908, or 0.062 gr. cal. of which certainly not more than about 0.014 gr. cal. can be attributed to some such common influence as solar variability; and this is less than the secular variation indicated by the monthly mean values of the group, which have for their extremes 1.957 for January, 1921, and 1.934, for June, 1921, and March, 1922, or a range of 0.023 gr. cal.

In Groups 2 and 3, in which the standard deviations of the solar constant determinations for Montezuma are ± 0.012 and ± 0.011 gr. cal., respectively, and for Harqua Hala ± 0.014 for both groups, the square of the correlation coefficients gives approximately 0.03 for the degree of relationship between the determinations of the value of the solar constant at the two stations. Of the extreme range in values, which at Harqua Hala is from 1.958 to 1.871, or 0.088 gr. cal., and at Montezuma from 1.954 to 1.877, or 0.077 gr. cal., not over 0.003 gr. cal. can be attributed to some such common cause as solar variability, an amount which is quite negligible.

It can not be without significance that for the period April, 1922, to November, 1924, inclusive, or for two years and eight months, the correlation between the day-to-day values of the solar constant determined at

[6] Yule, G. Udny. Theory of statistics, 5th edition, London, 1919, p. 311.

[7] Whipple, F. J. W. The significance of correlation coefficients. Meteorological Magazine, Feb. 1921, 56:20-21.

the two stations indicates a degree of relationship so slight as to be negligible. During this period the range in the monthly mean values was from 1.933 to 1.907, or 0.026 gr. cal.

On Figures 2 and 3 a cross has been located within the circles that inclose most of the dots, to show the mean value of the solar constant determinations indicated by the dots. A second cross has been located at a point to indicate the mean of solar constant values represented by the dots on the other corresponding figure. These two crosses fall on a line making an angle of very nearly 45° with the axes of ordinates and abscissas, which indicates that the results as summarized above are not inconsistent with Abbot's finding of a high correlation coefficient between the means of groups of synchronous values at Montezuma and Harqua Hala, arranged in order of magnitude of the solar constant determinations at Montezuma.[8] Such a grouping eliminates very largely the day-to-day variations discussed above; and the correlations found are the result of secular changes occurring during the period covered by the three groups, and not real correlations between actual day-to-day changes free from secular variations.

Furthermore, during the period April, 1922, to November, 1924, inclusive, a solar constant value is given on 827 days, and on 299 of these days, or on 1 day out of 2.78, values obtained at both stations were included in the mean for the day. The mean value for the whole period is 1.922. On 36 days the value was less than 1.900, and on 6 of these days, or on only 1 day out of 6, was the value derived from determinations made at both stations. On 35 days the value was 1.940 or above, and on 4 of these, or on 1 day out of 8.75, the value was derived from determinations made at both stations. Thus, while more than one third of the daily values have been derived from measurements made at both stations, this is the case with only about one seventh of the values that depart from the mean by more than ±1%.

In view of the above, and for the further reason that one out of every six of these extreme values is by Abbot graded $U+$ or U (rather unsatisfactory or unsatisfactory), they are not entitled to as much weight as the more nearly average values.

Abbot holds the view that since there are more *values with large departures* than theory calls for, this is a proof of solar variability.[9] It is not unusual to find such an excess however.[10] Further, in this particular case, it has been shown above that these extreme values have not the same degree of accuracy as the remaining values. Therefore the excess in their number, which is small numerically, can not be accepted as evidence of solar variability.

It seems evident, therefore, that the day-to-day variability of the solar constant determinations, the standard deviation of which is less than ±0.70 per cent, depends largely upon whether the solar constant value is derived from determinations made at only one or at both stations; that it reflects unavoidable inaccuracies in pyrheliometric readings, and in extrapolating the readings to zero air mass; and that short-period solar variability, if it exists, falls within the limits of the probable error of the determinations.

[8] Abbot, C. G., Solar variation and forecasting, p. 20, Smithsonian Misc. Coll., vol. 77, No. 5.

[9] Solar variability and forecasting. Smithsonian Misc. Coll., vol. 77, No. 5, pp. 16-18.

[10] Brenet, David. The combination of observations. (Cambridge, 1917) p. 33.

THE PROBABLE 24-HOUR TEMPERATURE CHANGE (7 A. M. TO 7 A. M.) AT MONTGOMERY, ALA.

By JESSE W. SMITH and WELBY R. STEVENS

[Montgomery, Ala., Weather Bureau Office, May 18, 1925]

In this study the probable temperature change for the 24-hour period 7 a. m. to 7 a. m., 90th meridian time, at Montgomery, Ala., has been determined by means of the Gram-Charlier frequency curves for each month of the year, based on 1,000 observations for each month.

The temperature changes were determined from the a. m. observations as recorded on Form No. 1001-Metl., beginning with 1924 and going back far enough to include 1,000 days in each monthly distribution. Each temperature was taken to the nearest even degree before the change was computed, thus giving the change in 2° units. This was done in order to give actual changes considered in the verification of forecasts.

The Gram-Charlier curves were selected because of the relative ease with which they may be computed and their flexibility, which promised good fits in all cases. Reference to Figure 1 shows that very good fits were obtained. It is the belief of the authors that the Gram-Charlier curves are particularly well adapted to meteorological distributions, because of their capacity to take care of both skewness and excess, which are likely to be encountered in appreciable degree, especially in monthly distributions.

It seems unnecessary to give a detailed description of the method of fitting these curves. Reference is made to Fisher,[2] where a lucid explanation may be found, both of the mathematical development and practical application. However, for practical application, tables [1] will be necessary containing the values of the generating function $\varphi_0(z) = \frac{1}{\sqrt{2\pi}} e^{-z^2:2}$ and its derivatives up to at least the fourth order.

Computations and the necessary control checks were made for each month, of which only January is shown, in Table 1, to illustrate the method.

Perhaps slightly better fits would have been obtained had the parameters been computed by the method of least squares instead of the method of semi-invariants, but the arithmetical labor entailed would have been almost prohibitive.

It is well known that in dealing with a limited series of observations the third and fourth moments, or in this case the third and fourth semi-invariants, are liable to considerable error, due to the chance presence of a few large departures. It was found in most of the calculations that this error was sufficient to cause a slowing up in the rate of increase near the tails of the curves, or in some cases enough to cause serious secondary inflections. It was found possible to eliminate this undesirable situation by neglecting, in the computation of the third and fourth semi-invariants, the observations at the tails beyond the value $z = (x - \lambda_1) : \sigma > 4$. Inasmuch as never more

[1] Fisher, Arne, Mathematical Theory of Probabilities, New York, 1923.

[2] Jørgensen, N. R., Undersøgelser over Frequensflader og Korrelation, Copenhagen, 1916.

than five observations were neglected, it appears that there can be no serious objection to such a procedure.

Table 2 shows, by months, the probability of a. m. temperature changes exceeding the stationary limits used in the verification of forecasts. The small chance of a temperature change exceeding 6° in the summer months is noteworthy. In August both the observed frequency and the calculated frequency of such changes amount to only 8 in 1,000.

Figure 1 shows the observed distribution and the Gram-Charlier curves of best fit, as well as the type equation, and all the constants. An interesting feature is the persistent negative skewness, even in those months when the annual march of temperature is downward. This nega-

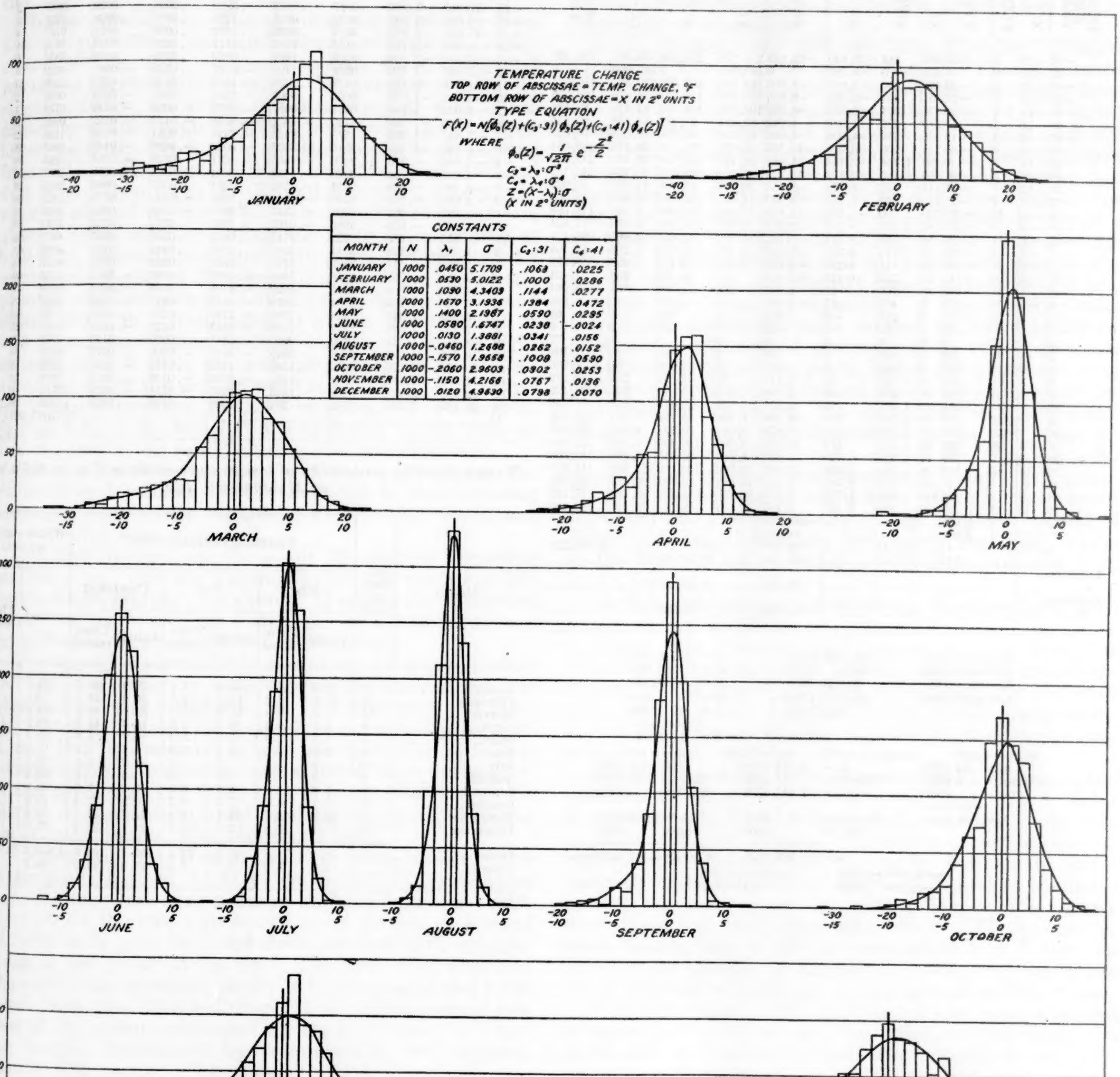


FIG. 1

tive skewness seems to be due, at least in part, to the steep temperature gradient in advance of passing HIGHS, giving rise to sudden and sharp falls in temperature, after which the rise is more gradual.

TABLE 1.—(A) *Computation of parameters, January*

Temperature change	X	F(X)	XF(X)	X^2	$X^2F(X)$	X^3	$X^3F(X)$	X^4	$X^4F(X)$	$(X+1)^4$	$(X+1)^4F(X)$
−44	−22	1	−22	484	484	−10, 648	−10, 648	234, 256	234, 256	194, 481	194, 481
−42	−21	0	0	441	0	−9, 261	0	194, 481	0	160, 000	0
−40	−20	1	−20	400	400	−8, 000	−8, 000	160, 000	160, 000	130, 321	130, 321
−38	−19	1	−19	361	361	−6, 859	−6, 859	130, 321	130, 321	104, 976	104, 976
−36	−18	1	−18	324	324	−5, 832	−5, 832	104, 976	104, 976	83, 521	83, 521
−34	−17	1	−17	289	289	−4, 913	−4, 913	83, 521	83, 521	65, 536	65, 536
−32	−16	1	−16	256	256	−4, 096	−4, 096	65, 536	65, 536	50, 625	50, 625
−30	−15	4	−60	225	900	−3, 375	−13, 500	50, 625	202, 500	38, 416	153, 664
−28	−14	9	−126	196	1, 764	−2, 744	−24, 696	38, 416	345, 744	28, 561	257, 049
−26	−13	7	−91	169	1, 183	−2, 197	−15, 379	28, 561	199, 927	20, 736	145, 152
−24	−12	3	−36	144	432	−1, 728	−5, 184	20, 736	62, 208	14, 641	43, 923
−22	−11	7	−77	121	847	−1, 331	−9, 317	14, 641	102, 487	10, 000	70, 000
−20	−10	18	−180	100	1, 800	−1, 000	−18, 000	10, 000	180, 000	6, 561	118, 098
−18	−9	19	−171	81	1, 539	−729	−13, 857	6, 561	124, 659	4, 096	77, 824
−16	−8	11	−88	64	704	−512	−5, 632	4, 096	45, 056	2, 401	26, 411
−14	−7	24	−168	49	1, 176	−343	−8, 232	2, 401	57, 624	1, 296	31, 104
−12	−6	31	−186	36	1, 116	−216	−6, 696	1, 296	40, 176	625	19, 375
−10	−5	29	−145	25	725	−125	−3, 625	625	18, 125	256	7, 424
−8	−4	44	−176	16	704	−64	−2, 816	256	11, 264	81	3, 564
−6	−3	53	−159	9	477	−27	−1, 431	81	4, 293	16	848
−4	−2	62	−124	4	248	−8	−496	16	992	1	62
−2	−1	67	−67	1	67	−1	−67	1	67	0	0
0	0	77	0	0	0	0	0	0	0	1	77
2	1	98	98	1	98	1	98	1	98	16	1, 568
4	2	110	220	4	441	8	880	16	1, 760	81	8, 910
6	3	87	261	9	783	27	2, 349	81	7, 047	256	22, 272
8	4	61	244	16	976	64	3, 904	256	15, 616	625	38, 125
10	5	43	215	25	1, 075	125	5, 375	625	26, 875	1, 296	55, 728
12	6	43	258	36	1, 548	216	9, 288	1, 296	55, 728	2, 401	103, 243
14	7	32	224	49	1, 568	343	10, 976	2, 401	76, 832	4, 096	131, 072
16	8	26	208	64	1, 664	512	13, 312	4, 096	106, 496	6, 561	170, 586
18	9	15	135	81	1, 215	729	10, 935	6, 561	98, 415	10, 000	150, 000
20	10	10	100	100	1, 000	1, 000	10, 000	10, 000	100, 000	14, 641	146, 410
22	11	1	11	121	121	1, 331	1, 331	14, 641	14, 641	20, 736	20, 736
24	12	2	24	144	288	1, 728	3, 456	20, 736	41, 472	28, 561	57, 122
26	13	1	13	169	169	2, 197	2, 197	28, 561	28, 561	38, 416	38, 416
Σ			{−1, 966 / 2, 011				−169, 270 / 74, 101}				
s_r			45		26, 741		−95, 169		2, 747, 273		2, 528, 223
m_r			.045		26. 741		−95. 169		2, 797. 273		
Adjusted s_r							−84, 521		2, 513, 017		
Adjusted m_r							−84. 6056		2,515.5326		

$\lambda_1 = m_1 = .0450$ $m_2 = 26.7410$ $s_4 = 2,747,273$

$\lambda_1^2 = m_1^2 = .0020$ $-m_1^2 = .0020$ $4s_3 = -330,676$

$\lambda_1^3 = m_1^3 = .0001$ $\lambda_2 = 26.7390 = \sigma^2$ $6s_2 = 160,446$

$\lambda_1^4 = m_1^4 = .0000$ $\sqrt{\lambda_2} = 5.1709 = \sigma$ $4s_1 = 180$

$138.27 = \sigma^3$ $s_0 = 1,000$

$714.95 = \sigma^4$ Check $= 2,528,223$

$m_2m_1 = 1.2033$ $m_3m_1 = -3.8073$ $m_2^2 = 715.09$ $m_2m_1^2 = .0535$

$m_3 = -84.6056$ $m_4 = 2,515.5326$ $\lambda_4 = 386.1338$

$-3m_2m_1 = -3.6099$ $-4m_3m_1 = 15.2292$ $4m_1\lambda_3 = -15.8788$

$2m_1^3 = .0002$ $-3m_2^2 = -2,145.2700$ $6m_1^2\lambda_2 = .3209$

$\lambda_3 = -88.2153$ $12m_2m_1^2 = .6420$ $3\lambda_2^2 = 2,144.8500$

$-6m_1^4 = .0000$ $m_1^4 = .0000$

$\lambda_4 = 386.1338$ Check $= 2,515.4259 = m_4$

$c_3 = \lambda_3 : \sigma^3 = -.6380$ $c_4 = \lambda_4 : \sigma^4_4 = .5401$

$-c_3 : 3! = .1063$ $c_4 : 4! = .0225$

TABLE 1.—(B) *Solution, January*

X	$X-\lambda_1$	$\frac{(x-\lambda_1)}{\sigma}$	ϕ_0 (Z)	ϕ_3 (Z)	ϕ_4 (Z)	7	8	9	10	11
−23	−23. 045	−4. 457	0. 0000	0. 0018	0. 0062	0. 0002	0. 0001	0. 0003	0	0
−22	−22. 045	−4. 263	. 0001	. 0048	. 0150	. 0005	. 0003	. 0009	0	1
−21	−21. 045	−4. 070	. 0001	. 0069	. 0205	. 0007	. 0005	. 0013	0	0
−20	−20. 045	−3. 877	. 0002	. 0100	. 0300	. 0011	. 0007	. 0020	0	1
−19	−19. 045	−3. 683	. 0005	. 0177	. 0481	. 0019	. 0011	. 0035	1	1
−18	−18. 045	−3. 490	. 0009	. 0290	. 0707	. 0031	. 0016	. 0056	1	1
−17	−17. 045	−3. 296	. 0017	. 0452	. 0980	. 0048	. 0022	. 0087	2	1
−16	−16. 045	−3. 103	. 0032	. 0665	. 1228	. 0071	. 0028	. 0131	3	1
−15	−15. 045	−2. 910	. 0058	. 0920	. 1382	. 0098	. 0031	. 0187	4	4
−14	−14. 045	−2. 716	. 0100	. 1186	. 1312	. 0126	. 0030	. 0256	5	9
−13	−13. 045	−2. 523	. 0166	. 1404	. 0882	. 0149	. 0020	. 0335	6	7
−12	−12. 045	−2. 330	. 0264	. 1496	−. 0027	. 0159	−. 0001	. 0422	8	3
−11	−11. 045	−2. 123	. 0419	. 1335	−. 1562	. 0142	−. 0035	. 0526	10	7
−10	−10. 045	−1. 943	. 0605	. 0909	−. 3261	. 0097	−. 0073	. 0629	12	18
−9	−9. 045	−1. 749	. 0864	−. 0087	−. 5272	−. 0009	−. 0119	. 0736	14	19
−8	−8. 045	−1. 556	. 1190	−. 1071	−. 6736	−. 0114	−. 0152	. 0924	18	11
−7	−7. 045	−1. 363	. 1575	−. 2453	−. 7398	−. 0261	−. 0166	. 1148	22	24
−6	−6. 045	−1. 169	. 2015	−. 3933	−. 6622	−. 0418	−. 0149	. 1448	28	31
−5	−5. 045	−. 976	. 2478	−. 4965	−. 4631	−. 0528	−. 0104	. 1846	36	29
−4	−4. 045	−. 782	. 2939	−. 5488	−. 0864	−. 0583	−. 0019	. 2337	45	44
−3	−3. 045	−. 589	. 3354	−. 5240	. 3661	−. 0557	. 0082	. 2879	56	53
−2	−2. 045	−. 395	. 3690	−. 4144	. 7896	−. 0441	. 0178	. 3427	66	62
−1	−1. 045	−. 202	. 3909	−. 2335	1. 0776	−. 0248	. 0242	. 3903	76	67
0	−. 045	−. 009	. 3989	−. 0107	1. 1965	−. 0011	. 0262	. 4240	82	77
1	. 955	. 185	. 3922	. 2142	1. 0963	. 0228	. 0247	. 4397	85	98
2	1. 955	. 378	. 3714	. 3987	. 8086	. 0424	. 0182	. 4320	83	110
3	2. 955	. 571	. 3389	. 5175	. 3901	. 0550	. 0088	. 4027	78	87
4	3. 955	. 765	. 2978	. 5499	−. 0503	. 0585	−. 0011	. 3552	69	61
5	4. 955	. 958	. 2511	. 5029	−. 4195	. 0535	−. 0094	. 2952	57	43
6	5. 955	1. 152	. 2054	. 3959	−. 6557	. 0421	−. 0148	. 2327	45	43
7	6. 955	1. 345	. 1614	. 2586	−. 7397	. 0275	−. 0166	. 1723	33	32
8	7. 955	1. 538	. 1222	. 1193	−. 6843	. 0127	−. 0154	. 1195	23	26
9	8. 955	1. 732	. 0890	. 0000	−. 5341	. 0000	−. 0120	. 0770	15	15
10	9. 955	1. 925	. 0625	−. 0849	−. 3441	−. 0090	−. 0077	. 0458	9	10
11	10. 955	2. 126	. 0416	−. 1344	−. 1536	−. 0143	−. 0035	. 0238	5	1
12	11. 955	2. 319	. 0271	−. 1494	−. 0092	−. 0159	−. 0002	. 0110	2	2
13	12. 955	2. 513	. 0169	−. 1413	. 0945	−. 0151	. 0019	. 0037	1	1
14	13. 955	2. 706	. 0102	−. 1201	. 1299	−. 0128	. 0029	. 0003	0	0
Σ								5. 1706	1, 000	1, 000

TABLE 2.—*The probability of temperature changes (7 a. m. to 7 a. m.) at Montgomery, Ala.*

Month	Stationary limit	Exceeding stationary limit						Within stationary limit	
		Rise		Fall		Combined			
		Actual	Theoretical	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical
January	10	13. 0	13. 3	13. 9	13. 4	26. 9	26. 7	73. 1	73.3
February	10	12. 8	12. 2	12. 1	12. 5	24. 9	24. 7	75. 1	75.3
March	10	7. 9	8. 9	11. 3	10. 3	19. 2	19. 2	80. 8	80.8
April	8	5. 1	5. 6	9. 2	8. 6	14. 3	14. 2	85. 7	85.8
May	8	1. 5	1. 6	3. 2	3. 0	4. 7	4. 6	95. 3	95.4
June	6	2. 0	1. 5	2. 4	2. 0	4. 4	3. 5	95. 6	96.5
July	6	. 5	. 4	. 7	1. 0	1. 2	1. 4	98. 8	98.6
August	6	. 1	. 2	. 7	. 6	. 8	. 8	99. 2	99.2
September	6	1. 2	1. 6	4. 9	6. 0	6. 1	7. 6	93. 9	92.4
October	8	3. 3	3. 8	7. 5	8. 2	10. 8	12. 0	89. 2	88.0
November	8	10. 6	12. 7	14. 1	14. 4	24. 7	27. 1	75. 3	72.9
December	10	12. 1	12. 8	12. 3	13. 4	24. 4	26. 2	75. 6	73.8
Sums		70. 1	74. 6	92. 3	93. 4	162. 4	168. 0	1, 037. 6	1, 032. 0
Means		5. 8	6. 2	7. 7	7. 8	13. 5	14. 0	86. 5	86. 0

TWO WATERSPOUTS IN MOBILE BAY, JUNE 12, 1925

By ALBERT ASHENBERGER

[Weather Bureau Office, Mobile, Ala., June 30, 1925]

During the early forenoon of June 12, 1925, two waterspouts developed at Mobile on a shallow and nearly land-locked arm of Mobile Bay, just southeast of the city.

Weather conditions.—The sky was partly cloudy from 5 a. m. to 5:50 a. m., and cloudy afterwards. Only stratus clouds were visible, although these somewhat resembled strato-cumulus while the weather was partly cloudy. Later, the entire sky was overcast with layers of stratus clouds, some of which were quite dark at their lower margins. At 6:45 a. m. the clouds were moving from ESE. The surface wind direction was SW. till 5:51 a. m., then from the E. and SE. until 7:34 a. m., when it shifted to the NW. The wind movement was about 3 miles an hour during the three hours ending at 6:30 a. m., when it increased with gusts and registered a maximum velocity of 22 miles at 7 a. m. The barometric pressure rose 0.09 inch to 30.01 inches during the two hours ending at 8 a. m. Rain began at 6:20 a. m. and ended at 9.19 a. m., amounting to 3.34 inches. It was a light sprinkle until 6:43 a. m., and became excessive at 7:47 a. m., following the shift of wind to the NW.; 3.26 inches fell in the succeeding hundred minutes. The temperature at 6:45 a. m. was 73°, which was 3° lower than at 1 a. m., and it fell to 68° during the excessive rain.

Information from spectators of the waterspouts was collected and collated, and is included in the following account. Statements regarding details that could not be reconciled were discarded.

The first display was for about 15 minutes beginning at 6:10 a. m., and the waterspout moved westward 300 yards, disintegrating near shore. It was of the dumb-bell form, and as viewed at a distance of 1,000 yards was estimated to be about 15 feet in diameter.

The second waterspout began about 10 minutes after the first one ended; it lasted about 35 minutes and was observed by many persons. It was first observed from the Weather Bureau for five minutes beginning at 6:38 a. m. For two minutes it was perpendicular, and then became inclined toward the east about 4° from verticality. It was again watched from 7:04 a. m. to 7:08 a. m. No motion of translation could be detected by sighting, for about two minutes, with objects on land.

Viewed from the Weather Bureau office building, this waterspout, located 4,800 yards, S. 12° W., resembled a moderately dark gray pillar of uniform diameter visible from above the tree tops to the lower margin of a cloud of fairly dark gray hue, and there was but little enlargement of the pillar at its top. The trees that obscured the base of the spout are about 70 feet in height and 2,700 yards from the office building. The visible vertical section of the spout subtended an angle of some 10°; and the height, determined by computation, was approximately 860 yards. The angular width was about two and one-half times that of a 6-foot smokestack 2,800 feet due south, which indicates a diameter of approximately 26 feet. Rain and a smoke screen lessened the visibility, and the regular morning reading of the meteorological instruments made continuous observation of the phenomenon impossible.

J. T. Tucker, Otis Gilmore, and Theodore Brocker viewed it from a point of vantage on Tucker's bath-house pier, which extends 1,400 feet southeastward from the shore; they estimated that the base of the spout passed about a hundred feet east of the pier and 200 feet from where they were standing. A funnel-shaped projection from the under surface of a dark cloud was first seen, and it suddenly extended pencillike to the water, which was observed to be violently moving in a counterclockwise whirl, and piling up into a mound between 5 and 10 feet high and 60 feet in diameter, at the top of which was the slightly tapering tube which had increased to 15 feet in diameter. A loud roaring noise was heard, becoming more intense as the waterspout approached. The wind was sufficiently strong to cause the observers to hold to posts, but it did not in any way damage the pier or bath-houses, which are frail structures.

Advancing westward, the spout moved 1,400 yards along a path very slightly curved to the left, then remained nearly stationary for about 20 minutes, after which it progressed southwestward about 700 yards. When it reached the shore, toward which it had leaned, it parted and receded to the clouds, and the mound of water and spray suddenly fell, producing great waves in the body of water, which has a depth varying from 3 to 6 feet.

Neither waterspout caused strong winds on land when it approached the shore.

Heavy rain extended only about a mile from the Weather Bureau station. The rainfall in the immediate vicinity of the spouts was very light—probably less than 0.01 inch, as it wet only the surface of the sandy shore. It did not begin until the waterspout phenomena had ended.

About 10 minutes after the occurrance of the second waterspout, there was a whirlwind that lasted about 5 minutes. Mr. Cyril Anthony, who was 100 yards from shore standing on Ritchie's bath-house pier, which extends south-southeastward 200 yards, noticed the water violently agitated about a hundred feet east of the outer end of the pier, where an 18-foot launch was nearly overturned and half filled with water. The rattling of loose boards, two of which were raised 5 or 6 feet, on another pier parallel to the first and about 20 feet to the north, together with the advancing agitation of the water, indicated the whirl. The disturbance had raised a mound of water and spray about 2 feet high, moved along the north side of Ritchie's wharf, then crossed it and progressed southwestward about 250 yards before disintegrating.

CIRRO-CUMULI AND THUNDERSTORMS

By R. M. DOLE

[Weather Bureau, East Lansing, Mich.]

It has been observed repeatedly by the writer that the appearance of a certain type of Alto-Cumuli and Cirro-Cumuli (in the form of small balls) during the summer months is almost a sure sign of thunderstorms, and that clouds of this character often preceded the disturbances by a number of hours; also, the more vigorous and pronounced the type of cloud, the more violent the storms that follow. During 1924, between May and the middle of August, the sky was systematically watched and the types of clouds and the times of their appearance were carefully noted. The table below gives the results.

Month	Number of thunderstorms	A.-Cu. or Ci.-Cu. observed	Sky obscured or no Ci.-Cu. seen	Ci.-Cu. seen but no thunderstorm
May	5	4	1	0
June	12	10	2	1
July	13	9	4	3
August	4	3	1	1
Total	34	26	8	5

Thundershowers without the warning Ci.-Cu. being observed occurred on eight days, but were of a local nature, mild and merely overgrown Cumulus. In three of the eight cases overcast skies precluded any observations of the upper clouds. In two instances another kind of Cirro-Cumuli was observed. These were the flat form, very nearly covering the sky and were passing when high pressure areas of decided strength were dominating the weather. This flat type seems to denote stable conditions; the ball type unstable.

Actually 26 thunderstorms out of 34 were preceded by these clouds, or 76 per cent. The more violent thunderstorms with squalls and hail of a destructive nature were all preceded by small, detached patches of Cirro-Cumuli, the time of their appearance in advance of first thunder varying from one to twelve hours. It was also noted that Cirro-Cumuli in the morning were followed by afternoon thunderstorms, while the appearance of these clouds in the late afternoon or evening was followed by thunderstorms occurring after midnight or the next morning.

Observations of A.-Cu., Ci.-Cu. and Thunderstorms

Date	Time, speed, and direction of clouds	Time of thunderstorm and intensity
May		
3	At intervals on the 2d, rapid, from west	10:09 a. m.-12:45 p. m.
6	7 p. m. of the 5th, moderate, from west	5:25 p. m.
7	Noon of the 7th, moderate, from southwest	5:50 p. m.
13	7 p. m. of the 12th, slow, from north	10:55 a. m.-2:49 p. m
15	Sunset, moderate, from the north; no thunderstorm	
17	Cloudy, upper clouds shut out	3:53 p. m.
June		
8	Cloudy, upper clouds not visible, during day (7th)	3:00 a. m.
9	6:45 p. m. of the 8th, rapidly, from southwest	6:35 a. m.
11	A. m. of the 11th, moderate, from northwest	4:41 p. m.
12	P. m. 11th, moderate, from northwest	7:50 p. m.
17	P. m. 16th, also afternoon 17th, slow, from the west	6:33 p. m.
19	A. m. of the 19th, moderate, from northwest	D. N. a. m.
20	7 a. m., moderate, from west; 2:30 p. m. vigorous patch, moderate, from southwest.	3:10 p. m. Severe.
21	7 p. m. 20th, vigorous form, rapidly, from northwest	D. N. a. m.
22	A. m. 22d, rapidly, from the northwest	4:55 a. m. Moderate
24	P. m. 23d, moderate, from the west	4:55 a. m.
28	27th, at sunset, vigorous type, moderate, from northwest.	7:38 a. m. Severe.
30	P. m. of the 29th, moderate, from the north	1:00 p. m.
July		
1	None observed	4:15 p. m.
2	None observed; Cu. grew to Cu.-Nb	4:08 p. m.
7	Overcast to preclude view of upper clouds	6:11 a. m.
8	A. m. of the 8th, moderate, from the west	2:40 p. m.
9	Noon of the 9th, moderate, from the west	7:10 p. m.
12	None observed	11:35 a. m.
13	Like beach sand with A.-Cu	No thunderstorm.
16	Evening of the 15th, moderate, from the northwest	7:12 p. m. Vigorous.
18	Like beach sand, very rapid from northwest, with A.-Cu.	No thunderstorm.
19	In army formation with sheets of A.-Cu., moderate, from northwest.	Do.
21	9 a. m., also evening, moderate, from southwest	12:48 p. m. Severe. 11:15 p. m. Severe.
27	Sunset 26th, rapidly, from northwest; 2 p. m., rapidly, from west. (Vigorous patches in both cases.)	3:35 p. m. Severe. 8:15 p. m. Severe.
28	7:15 p. m. of the 27th, moderate, from the west	D. N. a. m.-1:00 a. m.
29	Evening of the 28th, moderate, from west; vigorous patch.	3:12 a. m. Vigorous. 4:54 p. m. Vigorous.
30	9 a. m. and 4 p. m., moderate, from the west	10:55 p. m. Vigorous.
31	3 p. m. 30th, moderate, from west	D. N. a. m. Vigorous
August		
2	A.-Cu. and Ci.-Cu. like beach sand passing rapidly all day from northwest.	No thunderstorm.
4	5 p. m. of the 3d, moderate, from the west	5:14 a. m. Moderate. 6:14 a. m.-8:58 a. m.
5	P. m. 4th, rapidly from the west	5:00 p. m. Severe.
6	Noon of the 6th, rapidly from the west	D.N. a. m. Moderate. 3:28 p. m.
8	None observed	12:24 p. m.

ARE PRESENT METHODS OF RAINFALL INSURANCE SOUND?

By CYRUS H. ESHLEMAN

[Weather Bureau Office, Ludington, Mich.]

Whether under the prevailing methods of rainfall insurance the assured are receiving as much protection as they think they are receiving and as much as the companies think they are furnishing, may be seriously questioned.

Insurance is written only against rainfall amounting to 0.10 inch or over. Even 0.01 inch is often sufficient to interfere with a program and keep crowds at home, and there are many unfavorable days when the total within a few specified hours does not reach 0.10.

About a year ago a home-coming celebration was held at Ludington, and the committee in charge took out insurance. The writer was asked to note carefully the time and amount of any rain that might occur. The committee was told that while they were being given some degree of protection, there was considerable possibility of dissatisfaction, for the reason already stated. An examination of rainfall records for the preceding season showed that in at least two-thirds of the unfavorable cases no insurance would have been received. No effort was made to dissuade the parties from taking out insurance but they were told of the exact working of the specifications.

It happened that no rain fell that week, so the insured were perfectly satisfied.

This summer, a few weeks ago, an out-of-doors carnival was held, and the managers took out insurance. Again the writer was asked to observe the rainfall and the parties were informed as to how the insurance might work out, though they were told the insurance was highly advisable as it would afford a considerable degree of protection. In this case also absolutely no rain fell during the week.

But the carnival committee had said that loss for a similar carnival several years ago was suffered owing to unfavorable weather. So the records were examined for

that period in order to learn whether any insurance would have been received had a policy been secured. It was found that very little rain fell. There was rain on two afternoons, but scarcely any at night during the carnival hours for which insurance would have been written. However, the grounds were wet and the sky overcast, and these conditions kept away large numbers of people.

In order to learn the averages through a period of years the rainfall records at Ludington from May 1 to September 30, in the 10 years from 1915 to 1924, inclusive, have been examined. The results are given in Table 1. All cases are counted, both afternoon and night, when during the hours from 2 to 5 p. m. or 6 to 9 p. m., a total of 0.01 or more fell and would apparently

TABLE 1.—*Number of times at Ludington, Mich., from May 1 to September 30, in the years 1915 to 1924, inclusive, when 0.10 or more of rain fell between 2 p. m. and 5 p. m., and number when 0.01 to 0.09, inclusive, fell*

Year	0.10 or more	0.01 to 0.09, inclusive.
1915	9	21
1916	14	19
1917	9	20
1918	5	19
1919	7	19
1920	9	8
1921	4	10
1922	10	8
1923	6	8
1924	7	20
Total	80	152

have seriously affected the program or attendance. The first column gives the number of times in each year insurance would have been received, the second column the number of times none would have been received, since the rainfall was less than 0.10 and not less than 0.01.

It is seen that the latter outnumber the former almost two to one. But the facts are even worse than the table indicates. There are times when light rain amounts to only a trace, or when thunderstorms threaten but do not actually strike the station; on such occasions the attendance may be badly affected. The number of such times averages about four per year, which added to the total makes the nonbenefiting instances decidedly more than double the benefiting.

The results would be somewhat more favorable were the policies to cover more than three hours. The fact that the period is made short to keep down the cost, without the probabilities being considered that the specified total of rain may not be reached, indicates misunderstanding on the part of many. A four-hour period would be preferable though costing considerably more. The whole day might be still better.

There is no doubt a rainfall of over 0.10 may be more damaging than a lighter one, and probably should have heavier insurance. But there should be some protection against the numerous lighter rains when events would also be interfered with. Probably about half as much for the lighter rains would be a fair amount.[1]

[1] Doubtless the question of the greater frequency of light rains would enter into the rate problem. As the writer points out, the lighter rains are about twice as frequent as those over 0.10 inch.—*B. M. V.*

NOTES, ABSTRACTS, AND REVIEWS

PROF. H. H. HILDEBRANDSSON, 1838–1925

Prof. Hugo Hildebrandsson, the distinguished Swedish meteorologist, died at Upsala, July 29, 1925. On August 19 he would have completed his eighty-seventh year. His death means something more than the passing of one who was active in contributions to meteorology throughout a long life. Prof. Hildebrandsson was the last survivor of the group of men who assembled at Leipzig in 1869 and founded the International Meteorological Organization. He was a contemporary and associate of such famous pioneers as Buchan, Buys Ballot, Hann, Jelinek, Neumayer, Scott, and Wild. With him, therefore, a great generation of meteorologists passes into history.

Hildebrandsson was born at Stockholm in 1838, and took his degree as doctor of philosophy at the University of Upsala in 1866. In 1878 he was appointed professor of meteorology at the same university and director of its meteorological observatory, a position which he held until his retirement in 1906. He was a member of the International Meteorological Committee for many years and served as its secretary from 1903 to 1906. He received the Symons medal of the Royal Meteorological Society in 1920.

While his scientific work in meteorology covered a wide range, he was particularly identified with the study of clouds and of atmospheric circulation. In these studies he was intimately associated with Teisserenc de Bort. He was instrumental in preparing the International Cloud Atlas, in organizing the international cloud observations in 1896–97, and in presenting the results of these epoch-making observations. He published jointly with Teisserenc de Bort a monumental history and digest of studies in dynamic meteorology, "Les Bases de la Météorologie Dynamique," one of the most striking features of which is its facsimile reproductions of early meteorological documents. The subject that interested him above all others was the general circulation of the atmosphere. Probably no other meteorologist has devoted so much industry to collecting and sifting the data bearing upon this subject, and few have done so much to elucidate it.—*C. F. T.*

ON THE APPLICATION TO METEOROLOGY OF THE ASTRONOMICAL CYCLE OF 744 YEARS

By M. GABRIEL

[Translation from Comptes Rendus, 181, No. 4, July 27, 1925, pp. 187-189, by B. M. Varney]

In a preceding note I anticipated applying the astronomical cycle of 744 years to meteorology, also the 372-year period and the half-period of 186 years. It is difficult to verify this hypothesis, for meteorological observations, even for temperature and rain, are scarcely two centuries long. The only phenomena noted by historians are the extremely cold winters and the severely hot summers. Arago has got together a list of the very abnormal seasons recorded during the course of several centuries. Evidently incomplete though it is, it nevertheless furnishes a valuable source of material.

A comparison of the dates reveals not only the cycle of 744 years, but also the period of 372, and generally even that of 186 years. There is to be found usually, in the intervals, a difference of one year more or less, but on the whole the coincidences are remarkable.

The severest winters experienced in the last two centuries belong to the years 1740, 1776, 1789, 1795, 1830, 1871, 1880, 1891, 1895, and 1917. Every one of these winters belongs to a series, appearing in the following table with the verification of the intervals between the dates:

TABLE 1.—*Recurrences of extremely cold winters*

1st series	2d series	3d series	4th series	5th series
995 186 +372 1553 187 1740	1403 187 1590 186 1776	859 744 1603 186 1789	864 372 1236 186 1422 186 1608 187 1795	1272 186 1458 372 1830

6th series	7th series	8th series	9th series	10th series
940 186 1126 373 1499 185 1684 187 1871	764 372 +187 1323 185 1508 186 1694 186 1880	1333 185 1518 373 1891	964 186 1150 373 1523 186 1709 186 1895	801 187 988 371 1359 185 1544 373 1917

Among the severely hot summers one notes especially those of the years 1793, 1811, 1846, 1893, and 1911. We find the same periodicity as for the winters (Table 2).

TABLE 2.—*Recurrences of severely hot summers*

1st series	2d series	3d series	4th series	5th series
1422 186 1608 185 1793	1251 373 1624 187 1811	1102 186 1288 185 1473 373 1846	1522 185 1707 186 1893	1540 186 1726 185 1911

Many more examples might be noted than there is room for in this note. Particularly, is it very interesting to find that all the winters designated by Arago from the 8th to the 12th centuries have their counterparts after about 744 years in the 15th to the 19th centuries. Such a series of coincidences can not be effects of chance; hence it seems logical to conclude that there is a parallelism between the astronomical cycle and the general circulation of the earth's atmosphere.

If the supposition is accurate, we should in the near future experience a heavy winter. It will be the counterpart, after 186 years, of the winter of 1740, and after 373 years, of that of 1553. The winter of 1740 was concentrated into January and February; if it was somewhat less rigorous in southern Europe, it was very cold in northern France and especially in England. The Seine and the Thames were icebound for weeks together, and the bridges at Rouen were swept away by ice gorges. The winter of 1552–53 was a terrible one for the soldiers of Charles the Fifth during the famous siege of Metz.

Shall we experience in 1926 the periodic return of these heavy winters? The near future will tell us whether or not the supposition is correct.

SCIENTIFIC CONGRESSES IN SWITZERLAND

The programs of two important scientific congresses held this summer at Davos-Platz, Switzerland, are printed below. The first is that of the International Commission on Solar Radiation, which is a commission of the International Meteorological Committee, its meeting being held on August 31–September 2, inclusive. The second is that of the Climatological Congress organized by the Davos Institute for Alpine Physiology and Tuberculosis Research, meeting from August 16th to 22d, inclusive. The programs indicate that the congress on solar radiation is intended essentially for discussion and action on a program for future work, and the climatological congress primarily for the presentation and discussion of scientific papers. The titles of the papers indicate that when published they will form a valuable survey, not otherwise easily obtainable, of the present status of research on the relations between high-altitude climate and health.—*B. M. V.*

THE INTERNATIONAL COMMISSION ON SOLAR RADIATION

1. The principal resolutions drawn at the first conference in Utrecht (September, 1923), especially those touching the proposal of the Central Institute for Europe on actinometric measurements.
2. Problems of actinometry, with reference to:
(*a*) Climatology (thermal variations through radiation). Report by A. Angström.
(*b*) Meteorology (optical-dynamical problems). Report by Hergesell and Süring.
(*c*) Agriculture.
(*d*) Medicine. Report by Dorno.
3. Short communication by Abbot on his recent work on the "solar constant," and concerning also the establishment of a large observatory in Asia or Africa for researches on solar radiation.
4. Proposal by Kimball on the possibility of creating an annual publication for assembling systematic observations of solar radiation, and on taking steps toward extending radiation studies to higher stations.
5. Communications from Gorczinsky: (1) The use of solar filters in actinometry, with some results obtained in the Saharan oases. (2) On new pyrheliographs and spectrographs for measuring solar radiations.
6. Proposal of Kalitin on the need of unifying solar filters used in the Michelsen actinometer for measuring solar radiatoin.
7. Communication from Süring on methods of testing actinometers and heliographs. Organization of subcommission on financial matters involving the Central Institute for Actinometry.

CLIMATOLOGICAL CONGRESS AT THE DAVOS INSTITUTE

GENERAL

Dr. Carrière, Berne: The relationship between the various climates of Switzerland and the health of the population.

Prof. Dietrich, Berlin: The importance of climatology and climate research in relation to the national health.

Prof. Hellpach, Carlsruhe: The psychological influence of Alpine surroundings.

Dr. King Brown, London: Climate of a big city and the dwellings of the poor.

Prof. Levi, Rome: The problems of preventive medicine and their international development.

Dr. Wehrli, Zurich: History of climatic treatment.

PHYSICAL-METEOROLOGICAL SECTION

Prof. Besson, Paris: Subject to be announced later.

Prof. Dorno, Davos: The climatology of the high mountains.

Prof. Hellmann, Berlin: Climatic extremes on the earth.

Prof. Kassner, Berlin: Hygrometric conditions of the air on the Island of Heligoland.

Prof. Linke, Frankfort: Atmospheric opacity as an element of climate.

Prof. Maurer and Lutschg, Zurich: Measurements of evaporation from open water-surfaces in the Alps.

Prof. Dr. Mercanton, Lausanne: Glacier studies in Switzerland.

Prof. Edgar Meyer, Zurich: The significance of the ozone content of the atmosphere in relation to solar radiation.

Prof. Palazzo, Rome: Studies in atmospheric electricity and radiation at the mountain observatory in Sestola (Appennines).

Dr. Pollak, Prague: Demonstration of his pyrheliometer.

Prof. Wigand, Halle: Atmospheric electricity in the open air.

BIOLOGICAL SECTION

1. PHYSIOLOGY

Prof. Abderhalden, Halle: Subject to be announced later.

Prof. Asher, Berne: On the conditions of blood formation and of the metabolism of iron.

Prof. Baglioni, Rome: Influence of climate on the central function and the organs of the higher senses.

Prof. Sophus Bang, Copenhagen: On the employment of a biological reaction for estimating climatic intensity of light.

Prof. Biedl, Prague: The relationship of climate to the glands of internal secretion.

Prof. Bürker, Giessen: The blood in the Alpine climate.

Dr. Cuomo, Capri: The Gulf of Naples, the character and therapeutic value of its climate.

Dr. v. Fellenberg, Berne: Iodine and environment.

Prof. Haecker, Halle: Climate and animal pigmentation.

Dr. Hediger, St. Moritz: The climate of the high mountains and arterial tone.

Prof. Hess, Zurich: Climate and sleep.

Prof. Baron v. Koranyi, Budapest: The physico-chemical influence of climate.

Dr. Laquer, Nymwegen: Climate and metabolism in general.

Prof. Loewy, Davos: The causes of the physiological effects of Alpine climate.

Dr. Mol, s'Gravenhage: On the marine climate of Holland.

Prof. Morpurgo, Turin: On adaptation to climate and to work on the high mountains during the period of senile involution.

Dr. van Oordt, Buhlerhohe: Climatology and climato-physiology of the sub-Alpine region.

Dr. v. Schroetter, Vienna: Immunity in respect to the high-mountain climate.

2. BOTANY

Dr. v. Morton, Vienna: The climate of Alpine caves and their plant life.

Dr. Schibler, Davos: The flora of the Landwasser Valley of Davos as an indication of its climate.

Prof. Senn, Bale: Influence of light and temperature in the Alps on the anatomy and physiology of plants.

CLINICAL SECTION

Prof. von Bergmann, Frankfort: Contribution to the diagnosis of the activity of pulmonary tuberculosis with respect to climatic influences.

Dr. Bernhard, St. Moritz: Heliotherapy in surgical diseases.

Prof. L. Blum, Strasburg: Alpine climate and maladies of nutrition.

Prof. Feer, Zurich: Climate and the diseases of children.

Prof. Ferrata, Pavia: Influence of the various climates on disorders of the blood.

Sir Henry Gauvain, London: A comparison of the effects of inland and marine treatment in the cure of surgical tuberculosis.

Prof. Gigon, Bale: Climate and pathological metabolism.

Prof. Hausmann, Vienna: Light and disease, with observations on the organization of biological researches in regard to light.

Prof. Leonard Hill, London: Influence of sunshine and open air on health.

Prof. His, Berlin: Constitution and climate.

Dr. Kalatz, Prosnitz: Subject to be announced later.

Prof. Kraus, Berlin: Climate and vegetative system.

Prof. Löffler, Zurich: Renal diseases and climate.

Prof. Michaud, Lausanne: Climate and heart disease.

Dr. Ruppanner, Samaden: Climate and thyroidism.

Dr. Smiles, London: Physical considerations in photo-therapy.

Prof. Sonne, Copenhagen: Physiological and therapeutical action of artificial light.

Prof. Staehlin, Bale: Non-tuberculous diseases of the respiratory organs in the Alpine climate.

Prof. Stepp, Jena: Effect of sunlight on bone formation.

Prof. v. d. Velden, Berlin: Value of climatic treatment in convalescence.

Prof. Veraguth, Zurich: Climate and nervous diseases.

Dr. Young, London: Subject to be announced later.

Prof. Zoja, Milan: Blood quantity and altitude.

LOOMING AND MULTIPLE HORIZONS

On looking out to sea on a clear day one expects to see an apparently straight line marking the horizon. It was rather surprising then on June 17, 1925, when looking seaward from Hampton Beach, Mass., to observe a sea horizon that was decidedly humped up in one direction (ESE.) and double to treble in another (NE.). The smoke of a steamer out of sight rose from beyond the loomed horizon. A schooner sailed on the lower of the compound horizons further round to the north. The Isles of Shoals looked like a city of skyscrapers of uniform height. To the east and southeast the loomed-up horizon was dominant, from east to northeast the normal (?) horizon was surmounted by the one or two extra horizon lines. The loomed horizon joined with the other farther and farther northward in the course of the hour from 10 to 11 a. m. The extending upper line of the loomed horizon became visible first in rather regularly spaced spots (marking air waves?) which developed columnar connections with the lower sea level as the top line became continuous. A rough angular measurement indicated the looming to be about eight minutes of arc.

Over the ocean there was the normal cool cushion of air, represented by the moderate sea breeze at 59° F. blowing in from the ocean (shore water 54.5° F.), over which was beginning to run a warm southwesterly wind, which became strong by mid-afternoon at points a few miles inland.—*C. F. Brooks.*

DROUGHT AND FLOOD IN MEXICO

The prolonged drought which with some slight interruptions has been seriously affecting the southwestern United States and northern Mexico during the past year, reached such serious proportions late in May in northern Mexico that cattle throughout the State of Chihuahua were dying of thirst and starvation, and the staple food crops were seriously threatened. The United States Consul at Chihuahua reports that city being put on a limited water supply. There was much suffering among the inhabitants of western Chihuahua, the mountain streams and other sources of water having gone completely dry. Lago Bustillos, one of the largest lakes, was dry for the first time, it is said, in the history of the State.

Planting of corn and beans, the staff of life of most of the people, had been put off in the hope of rain, which is usually adequate for planting before the onset of the rainy season proper about July 1.

Then came a three-day rain, described as being, for that region, "most extraordinary." It was estimated that more than an inch fell, enough to practically assure successful planting—but enough also to damage the wheat crop to some extent in parts of Chihuahua.

Newspaper clippings indicate that this downpour was followed in southern Mexico on the 6th and 7th of June by wind and rain storms which in Mexico City caused the collapse of many houses in the poorer districts, and which in the Isthmus of Tehuantepec brought serious floods. In the latter region more than 100 lives were reported lost. Several small villages were wiped out. The cities of Juchitlan and Tehuantepec were reported "almost submerged." Damage to railroad property was extreme; the track of the Tehuantepec Railway for many kilometers was destroyed; a freight train was swept "four miles from its track" by the rush of waters. Telegraphic communication was suspended.

One favorable result of the rains was the extinguishing of fires in the turpentine forests near Nexaca.—*B. M. V.*

TORNADOES IN IOWA DURING JUNE, 1925

The following table is taken from a detailed report submitted by Mr. Arthur H. Christensen, Weather Bureau office, Des Moines, Iowa.

Iowa Tornadoes during June, 1925

Nearest towns	Date	Time	Direction of movement	Length of path	Persons killed	Persons injured	Estimated damage
I. Milford	1	P. m.	SW. to NE.	Short	0	0	....
II. Glenwood and Silver City.	2	4 p. m. to 5 p. m.	SW. to NE.	45 miles	0	4	$50,000
III. Onawa, Monona County, to Cushing, Woodbury County.	2	4 p. m. to 5 p. m.	SW. to NE.	46 miles	0	4	480,000
IV. Red Oak, Montgomery County.	2	6:10 p. m.	SW. to NE.	11 miles	0	5	100,000
V. Adair, Adair County.	2	8:30 p. m.	SW. to NE.	20 miles	3	3	100,000
VI. Northwest part of Iowa County.	2	10:15 p. m.	SW. to NE.	Short	0	0	....
VII. Neola, Pottawattamie County.	3	5:30 p. m.	SW. to NE.	5 miles	0	0	} 750,000
VIII. Neola and Persia.	3	6 p. m.	S. to N.	10 miles	1	21	
IX. Jefferson, Greene County.	3	9 p. m.	SW. to NE.	15 miles	0	1	10,000
X. Alexander, Franklin County.	11	4 p. m. to 4:45 p. m.	SW. to NE.	15 miles	1	18	350,000
XI. Dumont, Butler County.	11	4:30 p. m.	SW. to NE.	1 mile	0	0	} 150,000
XII. Greene, Butler County.	11	5 p. m.	SW. to NE.	2 miles	0	0	
XIII. Carrville, Floyd County.	11	6:30 p. m.	SW. to NE.	¼ mile	0	0	
XIV. Nashua, Chickasaw County.	11	6:30 p. m.	SW. to NE.	Short	0	0	
XV. Tabor, Fremont County.	28	2 a. m.	NW. to SE.	6 miles	0	0	10,000
Total				170 miles	5	56	2,000,000

INTENSE RAINSTORM OF JULY 3, 1925, DUBUQUE, IOWA

Mr. H. Merrill Wills, in charge of the Weather Bureau station at Dubuque, reports that during the evening of July 3, 1925, the city was visited by a rainstorm of unusual intensity, the second of the sort within 19 days following nine consecutive months of deficient precipitation. The total rainfall of this second storm was 3.47 inches (3.19 inches having been recorded in the first, during the night of June 14–15). The greatest falls within limited periods were: 5 minutes, 0.46 inch; 10 minutes, 0.81 inch; 15 minutes, 1.12 inches; 30 minutes, 1.86 inches; 1 hour, 2.29 inches; 2 hours, 3.22 inches.

Including the two storms just passed, 25 have brought precipitation exceeding 3 inches in 24 hours at Dubuque since 1874, or an average of one every two years.

The depressions along the wind-shift lines of which the two recent storms took place were of no unusual intensity. On July 3, occurred a maximum temperature of 96° at 2:30 p. m., the wind having been previous to that time SW., but shifting then to NW. and W., whence at about 5 p. m. it returned to SW. with the beginning of the rain, and so continued through most of the storm, reaching a maximum velocity of 37 miles per hour. The temperature dropped from 94° at 4:50 p. m. to 69° at 6 p. m.

Typical accompaniments of a severe thunderstorm are noted in the report: In this case the killing of two persons and injury of another; extensive damage to trees, gardens, telephone and other wire systems; flooding of sewers, streets, and basements. The estimate of total property damage is $50,000.

[With reference to the maximum recorded wind velocity, the question may be raised as to whether the Weather Bureau anemometer was located in the path of greatest wind force in this storm. In another part of the city a portion of the roof of a wagon factory was blown off and a side wall blown in; this, together with the destruction of large trees, indicates a degree of damage incommensurate with a wind velocity of only 37 miles per hour. This velocity is that of a "high wind," force 7, on the Beaufort scale, for which the specification is: "Whole trees in motion; inconvenience felt when walking against wind." For the specification which seems to describe this storm, namely, "trees uprooted; considerable structural damage occurs," the wind is a whole gale, force 10, velocity 55–63 miles per hour.]—*B. M. V.*

INCIPIENT TORNADO IN IDAHO

F. P. HOLT

Mr. Fred P. Holt, a former employee of the United State Weather Bureau, supplies us with the following particulars of a phenomenon observed by him in southeastern Idaho on July 4, 1925. It was evidently a tornado in the making; its failure to develope into a destructive whirl must be ascribed to the unfavorable atmospheric conditions near the surface of the ground:

About noon I observed a typical tornado which did not reach destructive proportions. A thunderstorm was approaching from the south, following the Portneuf River Valley, and a horizontal stratum of cloud at an estimated elevation of about 1,500 feet was accompanying the approaching storm. My attention was attracted to a small suspended mass of cloud which quickly assumed the form of an inverted cone. This cone rapidly became longer and more slender and the lower extremity swung irregularly from side to side from the vertical. As the storm approached, the rapid rotary spiral motion was distinctly observed with a very rapid vertical motion.

At its maximum development, I estimate the column to have been 500 to 800 feet long. At no time did it extend more than halfway from the cloud stratum to the valley floor.

From the maximum development above described, the swaying trunk gradually became shorter and shorter and my last observation was of a small agitation on the under surface of the cloud stratum. * * *

MASCART ON CHANGES OF CLIMATE

Mascart, Jean: Notes sur la variabilité des climats. Documents Lyonnais, Études de Climatologie, première partie, introduction générale historique. Lyon. M. Audin et Compagnie. (Not dated.)

Not since the publication of Ward's discussion of changes of climate, in his *Climate, Considered Especially in Relation to Man*, have climatologists been furnished with a more useful work. The director of the Lyon Observatory set himself a tremendous task. The result might almost have been called a "Handbook on the Variability of Climates."

Concise outlines of the historical development undergone by the various hypotheses of climatic change occupy each a short chapter. There is no lack of searching criticism and sprightly comment on the contradictions revealed by comparison of the different hypotheses. Nor has Mascart hesitated to include the views of the less authoritative writers or even of the occasional "vulgarisateur." In spite of the feeling that perhaps the work is thus a bit encumbered, one concludes that to quote them has after all served a purpose.

The author has avoided repetition of citations by wisely placing most of the references in a bibliography, compressed into some 60 pages near the end of the book. About a thousand authors are cited; probably not all readers will agree that the most important contribution of each has been included. But whatever the slight failing in this regard, it fades into insignificance in comparison with the vast usefulness of the whole. A valuable feature of this bibliography are the numerous references to abstracts and reviews.

To some readers the complex array of hypothesis and counterhypothesis will but prove that the whole question of changes of climate is in a bad way. To others it will distictly indicate hope of progress. That is the spirit of the "Critical Résumé" and "Conclusions." They constitute a diagnosis which everyone interested in the question will do well to read with care. The author emphasizes the value of a great erudition as the basis for acquiring that broad *and rare* perspective which alone can furnish adequate foundation for research into this baffling subject. He presents, moreover, a vivid arraignment of meteorology and climatology as having progressed in spite of the data which they have amassed, not because of them. The trouble is statistical indigestion. Failure to recognize this has been the cause of much bootless researching. Not until climatologists are willing to put their data through drastic sifting processes capable of discovering the nature of terrestrial atmospheric changes, may they hope for any real progress toward the discovery of causes. Especially for those who have a tendency to enter somewhat light-heartedly into research on fluctuations of climate, Mascart has a clear message.—*B. M. V.*

METEOROLOGICAL SUMMARY FOR SOUTHERN SOUTH AMERICA, JULY, 1925

[Reported by Señor J. B. Navarrete, El Salto Observatory, Santiago, Chile. Translation by B. M. V.]

July in general was relatively rainy over the whole southern part of the continent, and especially so during the second half of the month.

On the 1st, pressure rose over the whole southern region, resulting in the establishment of an anticyclonic régime, with good weather, cold and frosts, which lasted until the 13th.

On the 3d an important depression appeared in the northwest in the latitude of Coquimbo Province, causing brisk winds and rain from Iquique to Illapel. The maximum precipitation was observed at Ovalle, 28 mm. On the 4th occurred the phenomenon of the compression of the cyclone by strong converging winds, in harmony with the laws of Guilbert.

In the Argentine during the 2d to 4th, there were rains between Bahia Blanca and Salta. On the 6th and 7th an important depression affected Buenos Aires Province, with strong winds and heavy showers. At Bahia Blanca, 14 mm. fell on the 6th.

On the 14th a considerable depression appeared in the west, while the southern anticyclone spread toward the interior of the continent. During the 15th–18th the major depression began to affect the central zone of Chile, causing bad weather and rains. The heaviest precipitation was observed at Valparaiso on the 17th, 51 mm. During the 19th–23rd the depression gradually spread southward, and rainy and windy weather continued to alternate with each other in the provinces of southern Chile. On the 20th, the velocity of the NW. wind at Juan Fernandez reached 1,700 m. p. m. [63.3 m. p. h.].

On the 24th a new depression appeared in the west. It began to affect the continent on the 25th. On the 26th, rainy and windy weather dominated the region from Valparaiso to Corral. At the Island of Mocha the north wind attained a velocity of 1,800 m. p. m. [67.1 m. p. h.]. On the 27th–28th the depression advanced southward, causing a decrease in pressure in that region.

On the 30th, a new depression passed on the south, the pressure falling to 736 mm. (981 mb.) at Punta Arenas on the 31st. It rained from Valdivia to Magellanes.

BIBLIOGRAPHY

C. FITZHUGH TALMAN, Meteorologist in Charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Associated factory mutual fire insurance companies.
Effects of tornadoes on factory buildings, with especial reference to the Missouri-Illinois-Indiana tornado, March 18, 1925. Boston. 1925. 25 p. illus. 18½ cm.

Bacmeister, A., & Baur, Fr.
Die klimatische Behandlung der Tuberkulose. 46 p. figs. 26½ cm. (Ergebnisse der gesamten Medizin. Bd. 7.)

Besson, Louis.
La pluie a Paris d'après cinquante années d'observations. [Paris. 1924.] 43 p. illus. 25½ cm. (Serv. phys. et mét. Observ. de Montsouris et de la Tour Saint-Jacques.) [Annales serv. tech. d'hygiène de la ville de Paris. T. 5, météorologie.]

Bradfield, F. B.
Aerodynamic properties of a hemispherical cup. With application to the hemispherical cup windmill and anemometer. London. 1921. 16 p. 24½ cm. (Aeron. research comm. Rep. & mem., no. 712.)

Brockmann-Jerosch, H.
Regenkarte der Schweiz. sheet. 48 x 64 cm. (Beilage zur "Vegetation der Schweiz, Beiträge zur geobotanischen Landesaufnahme." H. 12, Zürich, 1923.)

Brooks, C. E. P.
Evolution of climate . . . with a preface by G. C. Simpson . . . [2d ed.] London. 1925. 173 p. 22 cm.

Burmeister, Federico.
Dirección meteorológica. [Buenos Aires. 1925.] p. 103–119. illus. plates. 27 cm. [Mem. corres. al ejer. de 1924 del Min. de agric.]

Chemulpo. (Korea.) Meteorological observatory.
Rainfall in Chôsen. (Korea.) Zinsen. 1925. 1, 1, 186 p. plates. 30½ cm. [Comprises numerous tables and charts.]

Coblentz, W. W., & Lampland, C. O.
Measurements of planetary radiation. p. 91–134. illus. plate. 31 cm. (Lowell observ., Bull. no. 85, v. 3, no. 10.)

Dines, W. H.
Table of temperature, pressure and density at different levels up to 20 kilometres. London. 1919. [1 p.] 24½ cm. (Adv. comm. for aeron. Rep. & mem., no. 509.)

Fage, A.
Description of a hot-wire anemometer which is sensitive over a large range of wind speed. London. 1919. 8 p. plates. 24½ cm. (Advis. comm. for aeron. Rep. & mem., no. 556.)

Febrer, Joaquim.
Pluges a Catalunya durant l'hivern de 1923–24 i la primavera de 1924. Barcelona. 1925. 16 p. illus. 22 cm. (Serv. met. de Catalunya. Notes d'estudi. no. 30.)

Fischer, Karl.
Die Grundgleichungen des Wasserhaushaltes eines Flussgebietes. 12 p. 22½ cm. (Sonderab.: Zentralblatt der Bauverwaltung. H. 18, Jahrg. 1925.)

Fischli, Fritz.
Aeronautische Meteorologie. 2. V. umgearb. Aufl. Berlin. 1924. 295 p. illus. plates (part fold.) 23 cm. (Bib. für Luftschiff. und Flugtech. Bd. 7.)

Gregory, Richard.
British climate in historic times. p. 248–258: 343–356. illus. 25 cm. [Geogr. teacher, v. 12, pt. 4–5, 1924.]

Huntington, Ellsworth, & Cushing, Sumner W.
Principles of human geography. 3rd ed., rev. New York. 1924. xviii, 430 p. illus. (incl. maps.) diagrs. 23½ cm.

Italy. Servizio idrografico.
Osservazioni pluviometriche raccolte nel quinquennio 1916–1920. Roma. 1925. viii, 139 p. 34½ cm. (Pubbl. N. 1, Serv. idrog. v. 4. Italia peninsulare e isole. Ordinate Filippo Eredia.)

James, Preston E.
Climate of Trinidad, B. W. I. Washington. 1925 p. 71–75. illus. 31 cm. (Repr.: Mo. wea. rev., Feb., 1925, v. 53.)

Kessler, Paul.
Das Klima der jüngsten geologischen Zeiten und die Frage einer Klimaänderung in der Jetztzeit. Stuttgart. 1923. 38 p. 23 cm.

Kornmann, Frank.
Das Klima Lugano's. Seine ärztlichen Indikationen und Kontraindikationen. Bern. 1924. v, 143 p. illus. 23½ cm.

Lundegårdh, Henrik.
Der Kreislauf der Kohlensäure in der Natur. Ein Beitrag zur Pflanzenökologie und zur Landwirtschaftlichen Düngungslehre. Jena. 1924. viii, 308 p. illus. 24½ cm.

Marini, Ludovico.
I principali tipi di tempo dell'Adriatico. Roma. 1924. 37 p. figs. 24½ cm. (Rivista marittima, Nov. e Dic. 1924.)
Risultati dei lanci di palloni piloti eseguiti nell'osservatorio del R. Istituto idrografico in Genova durante l'anno 1913. Roma. 1924. 101 p. plates. 31 cm. (Estr.: Mem. del R. Uff. cent. di met. e geof., v. 1, ser. terza.)

Murakoshi, Nobuo.
Ten years report of the meteorological observations made at Kungchuling agricultural experiment station of the South Manchuria railway company. Kungchuling. 1925. 47 p. figs. plates. 22½ cm. Appendix: Periodicity of Manchurian climatic factors in relation to agriculture. (Preliminary report.) p. 23–47. figs. (Bulletin no. 20.)

Normand, C. W. B., *comp.*
Storm tracks in the Bay of Bengal. A series of monthly charts for the period 1891–1923. Dehra Dun. 1925. unp. charts. 35 cm.

Novák, Václav.
Z praktické meteorologie. Brně. 1924. 12 p. illus. 24 cm. (Triumf techniky, 1925.) [Title and text in Bohemian.]

Oregon. State forester.
Fourteenth annual report . . . for the year ending December 31, 1924. Salem. 1925. 53 p. illus. 23 cm. [Includes discussion of relation of relative humidity to forest fires, p. 38–42.]

Pannell, J. R.
Variation of static pressure in a natural wind, as the velocity changes. London. 1917. 8 p. plate. 24½ cm. (Advis. comm. for aeron. Rep. & mem. (new ser.) no. 351.)

Pardé, Maurice,
Le Régime du Rhone. Étude hydrologique. 2 pts. Lyon. 1925. pt. 1–2. figs. 25 cm.

P[eignot,] G.
Essai chronologique sur les hivers les plus rigoureux, depuis 396 ans av. J. C., jusqu'en 1820 inclusivement; suivi de quelques recherches sur les effets les plus singuliers de la foudre, depuis 1676, jusqu'en 1821 . . . Paris. 1821. xv, 240 p. 21 cm.

Pollog, Carl Hanns.
Untersuchung von jährlichen Temperaturkurven zur Charakteristik und Definition des Polarklimas München. 1924. p. 165–253. figs. plates. 23½ cm. (Sonderab.: Mitteil. Geogr. Gesellsch. in München. 17. Bd., 2 H., 1924.)
Zur Frage der doppelten jährlichen Temperaturkurve in den Tropen. München. 1925. p. 187–203. fig. 24 cm. (Freie Wege vergleichender Erdkunde. Festgabe Erich von Drygalski zum 60. Geburtstag. Sonderdruck.)

Reisch, Rudolf.
Klima und Wein. v. p. 24½ cm. (Allgemeine Wein-Zeitung. 41. Jahrg., Nu. 12–14, 25. Juni, 10. Juli, 25. Juli, 1924.)

Sampaio Ferraz, J[oaquim] de.
Causas provaveis das sêccas do Nordeste Brasileiro. Rio de Janeiro. 1925. 30 p. illus. 26 cm. (Conferencia realisada no Club de engenharia no dia 20 de Dezembro de 1924.)

Sanson, Joseph.
La prévision du temps en agriculture. Paris. 1925. 320 p. illus. 19 cm.

Smith, G. L.
Note on recording meteorological instrument for kite balloon or kite. London. 1920. 6 p. plates. 25 cm. (Adv. comm. for aeron., Rep. & mem., no. 630.)

Sutton, L. J.
Upper currents of the atmosphere in Egypt and the Sudan. Cairo. 1925. 136 p. plates. 28 cm. (Min. pub. works, Egypt. Phys. dept. paper, no. 17.)

Taylor, G. I.
On the dissipation of eddies. London. 1919. 8 p. plate. 25 cm. (Adv. comm. for aeron. Rep. & mem., no. 598.)
Skin friction on a flat surface. London. 1919. 12 p. fig. plates. 24½ cm. (Adv. comm. for aeron. Rep. & mem., no. 604.)

Walter, A.
Relation between sugar crops and weather. Port Louis. 1922. 10 p. plate. 34 cm. (Royal Alfred observ., misc. pub., no. 5.)

Ward, Robert De C.
Are long-range weather forecasts possible? p. 366–367. 30 cm. [Outlook, v. 140, July 8, 1925.]

Webb, H. A.
Decay of eddies. London. 1919. 10 p. plate. 24½ cm. (Adv. comm. for aeron. Rep. & mem., no. 609.)

Welton, F. A., & Morris, V. H.
Wheat yield and rainfall in Ohio. p. 731–749. figs. 23 cm. (Journ. Amer. soc. agron., v. 16, no. 11, Nov., 1924.)

RECENT PAPERS BEARING ON METEOROLOGY

The following titles have been selected from the contents of the periodicals and serials recently received in the library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

Aero digest. New York. v. 7. August, 1925.
Gregg, W. R. Chasing weather secrets in airplanes. p. 421–422.

American philosophical society. Proceedings. Philadelphia. v. 64. no. 1. 1925.
Ward, Robert DeC. The importance of field-work in the study of climates. p. 64–67.

American society of heating and ventilating engineers. Journal. New York. v. 31. August, 1925.
Ingels, Margaret. How dusty is air? p. 415–418.

American meteorological society. Bulletin. Worcester, Mass. v. 6. July, 1925.

Abbot, C. G. Discussion of analysis [of solar radiation data]. p. 99–100. [Abstract.]

Baldwin, Henry I. Narrow climatic adaptability of forest tree seed. p. 105–107.

Clayton, H. Helm. Solar variation and the weather. p. 100–105.

Clough, H. W. A statistical analysis of solar radiation data. p. 97–98. [Abstract.]

Kimball, H. H. Smithsonian solar constant values. p. 96. [Abstract.]

Marvin, C. F. Solar radiation and the weather. p. 94–96. [Abstract.]

Annalen der Hydrographie und maritimen Meteorologie. Berlin. 53. Jahrgang. 1925.

Milch, Wilhelm. Über Reibung und Austausch infolge von Turbulenz in der Atmosphäre. p. 113–126. (April.)

Arnold-Alabieff, W. Russischer Eisnachrichtendienst auf der Ostsee und seine Eigenarten. p. 171–172. (Mai.)

Moltschanoff, P. Über vertikale Geschwindigkeiten der Pilotballone nach Beobachtungen des Aerologischen Observatoriums in Pavlovsk. p. 163–170. (Mai.)

Beiträge zur Physik der freien Atmosphäre. Mürchen. Band 12. Heft 2. 1925.

Ahlborn, Fr. Zyklonen und Antizyklonen im Mechanismus der Atmosphäre. p. 63–92.

Baur, Franz. Ueber mehrjährige Witterungsperioden und die Anwendung der Periodogrammanalysis zu ihrer Aufdeckung. p. 138–139.

Defant, A. Schwingungen einer zweifach geschichteten Atmosphäre und ihr Verhalthis zu den Wellen im Luftmeer. p. 112–137.

Kostarew, O. Ein Modell der atmosphärischen Bewegung mit geradlinigen Isobaren. p. 93–100.

Peppler, W. Ergänzungen zu meiner Arbeit "Die thermische Schichtung der Atmosphäre." p. 101–111.

Cambridge philosophical society. Transactions. London. v. 22. pt. 5. 1925.

Wilson, C. T. R., & Taylor, G. I. The bursting of soap-bubbles in a uniform electric field. p. 728–730. [With applications to rain drops.]

Ciel et terre. Bruxelles. 41 an. Juin-juillet 1925.

Jaumotte, J. Un météorographe pour sondage par avion. p. 113–127.

France. Académie des sciences. Comptes rendus. Paris. t. 180. 22 juin 1925.

Maurain, Ch., Salles, E., & Gibault, G. Sur la conductibilité et les courants électriques de l'atmosphère. p. 1955–1957.

Geographical journal. London. v. 66. August, 1925.

Tymms, F. The Oxford university arctic expedition, 1924: III. Meteorology. p. 120–126.

Heating and ventilating magazine. New York. v. 22. August, 1925.

Goldsbury, Paul W. Air conditions during sleeping hours. How night temperatures and humidities in a Boston suite in January compared with similar data for a country lodge in the summer. p. 68–70.

Ibérica. Tortosa. Año 12. 11 julio 1925.

Cirera, Ricardo. Principales observatorios de la Compañia de Jesús en las misiones. p. 41–44.

Időjárás. Budapest. v. 29. Május-június, 1925.

Az 1924, évi június 13-i biai viharforgategról. p. 73–82. [With German abstract, p. 101–103.]

Marine observer. London. v. 2. 1925.

Gherzi, E. Typhoons and statics. p. 132. (Aug.) [Discussion of "static" as a typhoon warning.]

Hennessy, J. Typhoons of the North Pacific and China Seas. p. 124–127. (Aug.)

Slee, J. A. Practical seagoing application of wireless to navigation and meteorology. p. 130–31. (Aug.)

Smith, L. A. Brooke. West Indian hurricanes, August and September, 1924. p. 141–147. (Sept.)

Matériaux pour l'étude des calamités. Genève. Année 1. Janvier-mars 1925.

Réthly, Antoine. Les calamités naturelles en Hongrie de 930 à 1876. p. 373–378.

Schwartz, E. H. L. The Kalahari project in relation to the distress in South Africa. p. 291–332.

Vallaux, Camille. Les raz de marée. p. 333–360.

Meteorologia pratica. Montecassino. Anno 6. Maggio-giugno 1925.

Crestani G. L'acqua che penetra nel pluviografo a galleggiante durante lo scarico. p. 116–119.

Dujardin-Beaumetz. Influenza del clima sulla tisi. p. 140–141.

Martini, E. Le zanzare durante un' annata secca. p. 139–140. [Abstr. Zeitschr. f. angew. Entomologie.]

Paoloni, B. La meteorologia agraria in Italia. p. 93–107.

Meteorologische Zeitschrift. Braunschweig. Band 42. Juni 1925.

Albrecht, F. E. H. Booth, Atmospheric dust and atmospheric ionisation. p. 251–253.

Baur, Franz. Die Verwendung der Korrelationsmethode in der Meteorologie. p. 247–250.

Forster, A. E. Eduard Mazelle. p. 234–235. [Obituary.]

Grundmann, G. Die Wasserhose auf dem Genfersee vom 3. August 1924. p. 244–247.

Hartmann, Wilh. Messungen der kurzewelligen Sonnenstrahlung auf dem Taunus-Observatorium. p. 242–244.

Kartschagin, W. Tagesgang der Sonnenstrahlungsintensität. p. 228–231.

Köppen, W. Ungleiche Ausnutzung des Klimas durch die Pflanzen. p. 237.

Prohaska, Karl. Klimaänderung innerhalb der letzten Jahrhunderte in Kärnten. p. 236–237.

Schoenrock, A. Emil Berg. Nekrolog. p. 235–236. [Obituary.]

Trey, F. Beitrag zur Erklärung der langen Dauer und der mehrfachen Schläge des Donners. p. 231–234.

Troeger, Heinz. Gerade und ungerade Niederschlagsjahre. p. 237–238.

Wiese, W, Studien über die Erhaltungstendenz der mittleren monatlichen Temperaturanomalien. 1. p. 217–225.

Zistler, Peregrin. Über primäre und sekundäre Druckwellen. p. 225–227.

National academy of sciences. Proceedings. Washington, D. C. v. 11. July, 1925.

Benedict, Cornelia Golay, Benedict, Francis, G., & Du Bois, Eugene F. Human metabolism in an environment of heated air. p. 300–373.

Rodebush, W. H., & Fiock, E. F. The measurement of the absolute charge on the earth's surface. p. 402–404.

National geographic magazine. Washington, D. C. v. 48. August, 1925.

Kerby, McFall. Toilers of the sky. Tenuous clouds perform the mighty task of shaping the earth and sustaining terrestrial life. p. 163–189.

Nature. London. v. 116. 1925.

Bauer, Louis A. Solar activity and atmospheric electricity. p. 45–46. (July 11.)

Glacier lassitude. p. 64–65. (July 11.)

Browne, H. C. Lightning-conductors. p. 242–243. (Aug. 15.) [Early history in France.]

Lehmann, J. F., and Osgood, T. H. The ionisation produced in air during the complete absorption of slow electrons. p. 242. (Aug. 15.)

Nature. Paris. 53 année. 1925.

Marcotte, Edmond. Le vol nocturne dans la brune. p. 282–286. (2 mai.); p. 296–301. (9 mai.)

Mercanton, P. L. La trombe du 3 août sur le lac Léman (lac de Genève). p. 383–384. (13 juin.)

Baldit, Albert. Un aspect de la météorologie moderne. Les surfaces de discontinuité. p. 6–10. (4 juillet.)

Nature magazine. Washington, D. C. v. 6. July, 1925.

Talman, Charles Fitzhugh. Lightning facts and fancies. p. 21–25.

Netherlands. Meteorologisch instituut. Mededeelingen en verhandelingen. Utrecht. no. 25. 1921.

Van Riel, P. M. The accuracy of barometer readings on board of moving ships. p. 1–8.

Photographic journal. London. v. 69. July, 1925.

Stevens, Catharine O. A plea for the application of kinematography to "wind wave" research. p. 362–365.

Physical review. Corning, N. Y. v. 26. July, 1925.

Schumann, T, E, W. On Elster and Geitel's theory of the electrification of rain drops. p. 105–110.

Popular astronomy. Northfield, Minn. v. 33. August-September, 1925.

Pickering, William H. Report on Mars, no. 30. p. 432–445. [Includes extensive discussion of Martian atmosphere.]

Pickering, William H. The shadow bands. p. 430–432.

Prussia. Meteorologisches Institut. Abhandlungen. Berlin. Band 7, Nr. 8. 1925.

Wussow, G. Darstellung der Niederschlagsverteilung in Deutschland durch Isanomalen.

Reale accademia dei Lincei. Atti. Roma. Rendiconti. v. (6) 1, fasc. 9. 1925.

Eredia, Filippo. La previsione dell' entità del prodotto del mandorlo di un' annata in base all' andamento della temperatura dell' aria e delle precipitazioni nel trimestre gennaio-marzo. p. 548–552.

Oddone, Emilio. Alterazioni nelle configurazioni isobariche portate dallo smorzamento dell' aria. p. 537–541.

SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING JULY, 1925

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1924, **52** : 42 and January, 1925, **53** : 29.

From Table 1 it is seen that solar radiation intensities averaged slightly above normal values for July at Washington, D. C., and Madison, Wis., and slightly below at Lincoln, Nebr.

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged close to the July normal at Washington, below the normal at Madison, and above the normal at Lincoln.

At Washington skylight polarization measurements made on 7 days give a mean of 43 per cent, with a maximum of 49 per cent on the 29th. At Madison, measurements made on 8 days give a mean of 58 per cent with a maximum of 64 per cent on the 10th. These are considerably below the normal values for July at Washington and slightly below at Madison.

On July 1 the radiation instruments at Washington were moved from the College of History, American University, to Temporary Building No. 2, of the Fixed Nitrogen Research Laboratory. This building is on the campus of the American University about 300 yards southwest of the College of History. The Marvin pyrheliometer is exposed in the morning outside a window facing southeast, and in the afternoon outside a window facing southwest, but the altitude above sea level is only 395 feet as compared with 418 feet in the old exposure. The horizontally exposed recording thermoelectric pyrheliometer is exposed on the roof 414 feet above sea level as compared with 451 feet at the old exposure. Also, it is shaded by the Fixed Nitrogen Research Laboratory, which is about 100 yards to the northeast, from a small section of the sky near the horizon. The polarimeter is exposed on a platform near the thermoelectric pyrheliometer.

The difference in exposures at the old and the new locations should not affect the readings of the instruments to a noticeable extent.

TABLE 1.—*Solar radiation intensities during July, 1925*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Sun's zenith distance	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Date	75th mer. time	Air Mass. A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.3	4.3	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
July 6	18.59			0.52	0.73						18.59
13	12.68		0.57								14.10
14	12.24					1.37	1.13	0.89			9.47
17	16.20				0.85	1.04					12.24
18	8.48	0.82	0.91	1.04	1.20						9.14
23	14.10	0.39	0.47	0.60	0.83	1.12					11.81
27	14.60		0.35								14.10
28	13.61				0.83						13.13
29	9.47		0.80	0.92	1.13	1.37	0.86				9.14
Means		(0.60)	0.62	0.77	0.93	1.22	(1.00)	(0.89)			
Departures		+0.02	−0.04	+0.01	+0.04	+0.05	+0.02	+0.09			

*Extrapolated.

TABLE 1.—*Solar radiation intensities during July, 1925*—Continued

Madison, Wis.

Sun's zenith distance	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Date	75th mer. time	Air Mass. A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
July 2	16.20				0.93						14.10
9	16.79						1.14				17.96
10	13.13				1.21	1.42	1.16				13.13
11	14.10					1.20					21.28
15	19.23				1.07	1.35					18.59
16	11.38				1.17						12.68
17	10.59				1.19						9.83
21	12.24				1.12	1.28					13.13
23	10.21				1.16	1.36					10.59
28	9.14				1.20						10.59
29	9.14				1.13						9.47
.30	10.59					1.31					9.47
Means					1.13	1.32	(1.15)				
Departures					+0.08	+0.05	+0.14				

Lincoln, Nebr.

Date	75th mer. time (e.)	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	Local mean solar time (e.)
July 4	12.68		0.73	0.84	1.06	1.28	1.05	0.87	0.66		10.21
6	16.20						1.08	0.85	0.70		16.20
7	16.79					1.25	1.03	0.88	0.73		17.96
8	19.23			0.90	1.08						15.65
10	17.37			0.83	1.08						19.23
11	17.96			0.91	1.07						18.59
13	17.37		0.75	0.88	1.08	1.34					16.20
14	15.11						1.10	0.94	0.79		15.65
15	18.50		0.82	0.94	1.11	1.31	1.04	0.84	0.68		16.20
16	10.59		0.92	1.05	1.19	1.41	1.16	0.99	0.84		8.18
17	9.47		0.77	0.85	0.99						7.87
18	10.97						0.89	0.72	0.57		11.38
21	10.21			0.45	0.69	1.08	0.84	0.62	0.49		9.47
23	10.21						0.94		0.62		8.81
25	15.11						0.96	0.77	0.62		15.11
Means			0.80	0.85	1.04	1.28	1.01	0.83	0.67		
Departures			±0.00	−0.04	−0.03	−0.04	−0.05	−0.05	−0.06		

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning—	Average daily radiation: Washington	Madison	Lincoln	Chicago	New York	Average daily departure from normal: Washington	Madison	Lincoln
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
July 2	475	493	617	508	428	−6	−44	+40
9	441	565	647	482	481	−40	+35	+64
16	470	486	577	396	403	−5	−26	+6
23	520	471	505	366	423	+56	−19	−40
Excess since first of year on July 29, 1925						+959	+1,736	+896

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The following table shows the average sea-level pressure for the month, as well as the highest and lowest barometric readings at a number of land stations on the coast and islands of the North Atlantic. The readings are for 8 a. m. 75th meridian time, and the departures are only approximate, as the normals are taken from the Pilot Chart and are based on Greenwich mean noon observations, which correspond to those taken at 7 a. m., 75th meridian time.

Station	Highest pressure	Date	Lowest pressure	Date	Average pressure	Departure
	Inches	*July*	*Inches*	*July*	*Inches*	
St. Johns, Newfoundland	30.26	22	29.68	14	29.94	−0.04
Nantucket	30.18	6	29.66	17	29.95	−0.03
Hatteras	30.18	1	29.72	17	29.99	−0.03
Key West	30.10	16, 17	29.98	14, 21	30.01	+0.03
New Orleans	30.14	12	29.82	15	30.04	+0.04
Swan Island	29.96	18	29.86	4, 5, 7,	29.90	−0.02
Turks Island	30.14	31	30.02	20, 21	30.07	+0.06
Bermuda	30.36	23	30.04	27	30.18	+0.07
Horta, Azores	30.56	5	30.06	24	30.36	+0.09
Lerwick, Shetland Islands	30.33	13	29.55	31	29.91	+0.13
Valencia, Ireland	30.40	11	29.35	19	29.97	−0.01
London	30.30	13	29.48	27	29.93	−0.05

It will be noticed that the average pressure was not far from the normal at most of the stations, while the daily changes were, for the most part, comparatively slight. According to the normals shown on the Pilot Chart, the number of days with winds of gale force on the North Atlantic is less for July than for any other month. Judging from reports received up to date, the number of gales during July, 1925, was less than usual over practically the entire ocean. Gales were reported on 3 days in the square between the thirty-fifth and fortieth parallels and the 5th and 10th meridians, and this was the maximum. In mid-ocean winds of gale force were reported on from 1 to 2 days only. No storm logs have been received as yet from vessels west of the 60th meridian, with the exception of the report of unusually strong trade winds on the 27th and 28th that will be referred to later. In view of the absence of any series of marked disturbances no ocean charts are presented for this month.

Taking the ocean as a whole more fog reports were received than in many years, and they were unusually evenly distributed. The number of days with fog was above normal over all the region north of the fortieth parallel; the maximum for any 5-degree square occurred between the 40th and 45th parallels and the 65th and 70th meridians, where fog was observed on 23 days; over the steamer lanes and off the European coast it was reported on from 10 to 15 days.

On the 1st, generally high pressure prevailed over the ocean, accompanied by light to moderate winds. On the 2d there was a *low* near Newfoundland, although no heavy winds were reported. At the time of observation on the 3d the conditions were practically the same as on the 2d, although later in the day a disturbance developed over the region between the thirty-fifth and fortieth parallels and forty-eighth and sixtieth meridians, and on the 4th southerly winds of gale force were encountered near 40° N., 50° W., accompanied by comparatively high barometric readings. On the 3d there was also a depression central near London with winds of force 7 in the westerly quadrants and also in the vicinity of the Straits of Gibraltar.

On the 5th and 6th high pressure with light to moderate winds was almost universal. On the 7th Belle Isle was near the center of a *low* that moved but little during the next 24 hours, and on the 7th and 8th moderate gales prevailed between the forty-fifth meridian and Newfoundland.

Mr. F. Krastin, observer on board the American S. S. *Comus*, Capt. H. F. Boyd, from New Orleans to New York, reports as follows:

At 11.40 a. m. on July 9 sighted waterspout in 27° 40′ N., 87° 20′ W., which moved in NW. direction about one-quarter of a mile off ship.

From the 9th to 17th the Icelandic *low* was apparently well developed, with comparatively high pressure in the British Isles until the 15th, when it began to fall. On different days during this period reports of southerly to westerly gales were received from vessels on the eastern section of the steamer lanes.

From the 17th to 19th a well-developed *low* over the British Isles remained nearly stationary until the 20th, when it began to fill in. It reached its greatest intensity on the 19th, causing northwesterly gales between the twentieth meridian and the European coast.

From the 20th to 25th there ensued another period of inactivity, with slight pressure gradients and light to moderate winds.

On the 25th there was a depression over Scotland that afterwards developed into the most severe disturbance of the month, and lasted until the 28th. This depression moved but little and the storm area covered only a limited region of the ocean east of the fifteenth meridian.

On the 27th and 28th unusually strong trade winds were encountered in the vicinity of the Canal Zone, as shown by report in table from the Japanese S. S. *Havana Maru*.

On the 30th an area of low pressure was central near Lerwick, and, moving slowly eastward, was over the North Sea on the 31st. No heavy winds were reported near its center on either day, although westerly gales prevailed between the forty-fifth and fiftieth parallels and the fifth and twenty-fifth meridians.

Ocean gales and storms July, 1925

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
North Atlantic Ocean			° ′	° ′				Inches					
President Harding, Am. S. S.	New York	Bremerhaven	39 50 N.	54 45 W.	3d	1 p., 3d	3d	29.72	S	SSW., 7	SSW.—	SSW., 8	S.-SSW.
Eastern Victor, Am. S. S.	Antwerp	Philadelphia	41 47 N.	48 55 W.	4th	2 a., 4th	4th	30.00	SW	S., 8	SW	SSW., 8	SSE.-SSW.
Parthenia, Br. S. S	Avonmouth	Montreal	52 43 N.	50 02 W.	7th	4 a., 8th	8th	29.71	W	SW., 8	NW	—8,	SW.-NW.
Eibergen, Du. S. S	Swansea	do	54 40 N.	31 08 W.	10th	11 p., 10th	11th	29.56	SW	SW., 9	W	SW., 10	
Maine, Dan. S. S	Port Talbot	do	54 33 N.	30 30 W.	11th	10 a., 13th	14th	29.70	WSW	WSW	W	W., 8	WSW.-W.
Lacuna, Br. S. S	Liverpool	Curacao	51 15 N.	10 10 W.	17th	7 p., 17th	20th	29.61	N	NW	NNW	NW., 9	Steady.
Ashtabula, Br. S. S	Sabine	Dublin	49 06 N.	12 09 W.	18th	11 p., 19th	20th	29.31	NNW	NNW., 7	E	NNW., 8	NNW.-E.
Putney, Br. S. S	Philadelphia	London	49 38 N.	7 50 W.	25th	11 p., 25th		29.81	SW	SW., 4		NW., 9	SW.-NW.
Vittorio Emanuel III, Am. S. S.	Cardiff	Philadelphia	50 37 N.	15 00 W.	26th	4 a., 26th	27th	29.77	NW	—, 8	NW	NW., 8	Steady.
Conrad Mohr, Nor. S. S	Shields	BatonRouge	50 35 N.	0 19 E.	27th	Noon, 27th	28th	29.48	W	W., 10	W	W., 11	Steady.
Havana Maru, Jap. S S	Balboa	Baltimore	12 25 N.	78 12 W.	27th	6 p., 27th	28th	29.73		NE		—, 7	NE.-ENE.
Waban, Am. S. S	Rotterdam	Galveston	48 00 N.	8 45 W.	30th	7 p., 30th	31st	29.84	SW	SW., 7	WNW	WSW., 8	SW.-WSW.-WNW.
Vardulia, Br. S. S	London	New York	48 34 N.	24 00 W.	30th	6 a., 30th	30th	29.82	WSW	WSW., 8	W	WSW., 8	WSW.-W.
South Atlantic Ocean													
West Corum, Am. S. S	Mobile	Montevideo	20 08 S.	38 45 W.	3d	4 a., 3d	4th	29.96	SW	SW., 7	SW	SW., 8	
South Pacific Ocean													
Tahiti, Br. S. S	San Francisco	Sydney, N. S. W.	27 50 S.	167 25 W.	1st	Midt., 1st	2d	29.56	NW	SW., 8	W	SW., 9	WSW.-SW.
Do	do	do	36 12 S.	175 20 W.	22d	10 a	22d	29.64	N	N	NE	N., 9	Steady.
Middleham Castle, Br. S. S.	Panama	Auckland	34 50 S.	157 W.	12th	4 p., 12th	13th	29.37	NW	SW., 6	S	SSE., 9	W.-SW.
North Pacific Ocean													
Challenger, Am. S. S	San Francisco	Seattle	42 05 N.	124 36 W.	3d		4th	29.90	N	N., 8	N	N., 9	Steady.
West Prospect, Am. S. S	Hongkong	San Francisco	39 26 N.	126 42 W.	3d	3 a., 5th	5th	30.02	NW	N., 7	N	N., 8	Steady.
Lebec, Am. S. S	San Pedro	Chile	14 30 N.	102 30 W.	7th	6 a., 8th	8th	29.61	E	ENE., 10	SSE	ESE., 10	E.-SSE.-SW.
San Tiburcio, Br. S. S	South America.	San Pedro	See	text.	9th	2 a., 10th	10th	28.90				—, 12	
Angers, Fr. S. S [1]	Marseille	Yokohama	25 08 N.	119 44 E.	8th			29.45				NE., 8	
Thomas, U.S.A.T	Honolulu	Guam	13 27 N.	138 E.	9th	11 p., 9th	11th	29.65	E	E., 8	S	S., 8	
Africa Maru, Jap. S. S	Yokohama	Victoria	47 25 N.	172 20 E.	13th	6 p., 13th	14th	29.78	SSE	SSE., 8	SW	SSE., 8	SSE.-SE.
Edgemoor, Am. S. S	Balboa	Honolulu	15 30 N.	108 50 W.	17th	10 p., 17th	22d	29.67	W	WSW., 5	SSW	S., 10	SSE.-SW.-WSW.

[1] Position of vessel approximate. Barometer—regular observation only—uncorrected.

NORTH PACIFIC OCEAN

By WILLIS EDWIN HURD

For the fifth successive month the North Pacific anticyclone continued in a well-developed state, and in July was scarcely disturbed by cyclonic influences, except in the north, where the Aleutian low fluctuated along or slightly into its boundary.

Although the low was practically absent from Alaskan waters on several days, yet it covered the upper part of the Gulf of Alaska from the 7th to the 13th, and the Aleutian Islands on several days preceding and following these dates, so that, particularly in the neighborhood of Dutch Harbor, the average pressure was below the normal for the month.

Pressure data for July for the several island stations in the eastern part of the North Pacific, as well as for a few stations on the American coast, are given in the following table:

Station	Average pressure	Departure from normal	Highest	Date	Lowest	Date
Dutch Harbor [1]	[2] 29.90	−0.12	30.32	26th	29.40	20th
St. Paul [1]	[2] 29.90	−0.05	30.34	26th	29.60	20th
Kodiak [1]	[2] 29.98	−0.02	30.22	15th	29.52	8th
Midway Island [1]	30.09	−0.01	30.20	[3] 14th	29.88	3d
Honolulu [4]	30.02	0.00	30.09	12th	29.89	15th
Juneau [4]	30.03	−0.02	30.33	15th	29.60	8th
Tatoosh Island [5]	30.11	−0.04	30.28	1st	29.89	21st
San Francisco [5]	29.97	−0.02	30.14	12th	29.78	17th
San Diego [5]	29.93	−0.04	30.02	24th	29.75	17th

[1] P. m. observations only.
[2] 28 days.
[3] And other date.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

Hawaiian weather was largely fair, under the influence of the anticyclone to the northward. The total rainfall was again below the normal, the amount, 0.67 inch, having a departure of 0.52 inch. The prevailing wind continued from the east, though the highest velocity was from the NE. at the rate of 27 miles an hour, on the 28th. The mean temperature did not vary over 3° from the normal on any day.

Pressure continued low along the Asiatic coast, but no severe storm seems to have developed, although two known typhoons, of moderate depth, influenced the northern islands of the Philippines and the China coast during the period from the 7th to the 17th. Reports of the moderate gales occurring in this area will be found in the table.

The weather over most of the ocean was mainly serene. No gales exceeding 9 in force were reported except from the Mexican coast region, where two cyclones, one of known hurricane violence, occurred.

Of the three vessels that up to the present time have furnished reports of these tropical storms, two ran into the hurricane of the 7th to 10th. On the afternoon of the 7th the American S. S. *Lebec*, southward bound, encountered a heavy squall from the east, force 10, in 14° 30′ N., 102° 30′ W. The vessel continued in the gale until noon of the 8th, at which time its position was 12° 30′ N., 100° 45′ W. The master of the British S. S. *San Tiburcio*, Buenos Aires to San Pedro, rendered the following account of later developments of this storm:

July 9, 4 p. m.: Barometer 29.78 (this and following readings uncorrected). Freshening wind. Moderate to rough sea, overcast and showery.

8 p. m., latitude 15° 29′ N., longitude 111° 39′ W.: Vessel steering N. 21 W. (true). Barometer 29.72. Strong wind, with occasional violent squalls of wind and rain. Rough sea. Sky heavily overcast.
10 p. m.: Barometer 29.60. Wind increasing to strong gale, with frequent squalls of hurricane force and torrential rain.
Midnight: Barometer 29.47. Whole gale, with frequent violent squalls of hurricane force; extremely heavy rainstorm. Rough sea and moderate NE. swell.
July 10, 1 a. m.: Barometer 29.20, and falling very rapidly. Wind backing (west).
1.15 a. m.: Turned vessel around to SE. and reduced to half speed.
2 a. m.: Barometer 28.90. Heavy storm. Wind of hurricane force; torrential rain accompanied by vivid lightning. Rough sea. Moderate NE. swell.
3 a. m.: Barometer 29.15, rising rapidly. Wind backing to SW.
4 a. m.: Barometer 29.35. Weather clearing and storm abating.
4.15 a. m.: Turned vessel around to course N. 45 W. (true). Proceeded full speed.
6 a. m.: Barometer 29.66. Strong wind, occasional heavy squalls of wind and rain, overcast, rough sea and heavy swell.

The second storm occurred during the second decade of July. The American S. S. *Edgemoor* was involved in rough weather for several days. The observer's report follows:

From Cape Mala on July 11 to midnight of the 26th, over the Great Circle to Honolulu (near 21° N., 144° W.) we had continuous heavy rain squalls. Only twice during this time did we get our position from observation.
On July 17, with sky overcast, squally with light rains, the wind which had been moderate began to slowly increase in force and rain squalls becoming heavier, each day increasing until the 22d, when wind attained a force of 10. Weather had cyclonic indications. On the 22d hove vessel to, heading south for 10 hours, when about 6 p. m. breaks showed in clouds and wind diminished to fresh, blowing from SSE.

The more or less stagnant condition of the atmosphere in middle and higher latitudes resulted in the formation of an extraordinary amount of fog over the entire width of the ocean along the northern sailing routes. In some part of the long and broad area between 170° W. and 150° E. it occurred on every day of the month. The American S. S. *West Chopaka*, Japan to San Francisco, experienced fog from the 19th, in 46° 30′ N., 149° 38′ E., until the 28th, in 46° 29′ N., 146° 01′ W. Fog was also frequent along our coast, especially from San Francisco southward to the 25th parallel.

NOTE.—American S. S. *Ohioan*, New York to San Pedro, Capt. L. C. S. Smith, Observer R. M. Pierce, second officer:

July 15, 14° 39′ N., 95° 40′ W., at 1.40 p. m.: Encountered a whirlwind which removed wooden boat covers and blew water 20 or 30 feet in air. This disturbance had an anticlockwise rotary movement, and after passing about 4 miles to the westward formed two waterspouts. Barometer read 29.79. Temperature of water, 81°.

ONE DESTRUCTIVE TYPHOON IN LUZON DURING JUNE

By REV. JOSÉ CORONAS, S. J.

[Weather Bureau, Manila, P. I.]

Although the northern part of Luzon suffered from heavy rains and floods in several days of June, yet only one destructive typhoon traversed the Philippines during this month causing great damage in several Provinces, but most particularly to the Provinces of Camarines Norte, Bulacan and Nueva Ecija. The Province of Camarines Norte, however, is the one that suffered most from the hurricane winds, floods and heavy rains, the barometer at Daet having fallen at least to 722.25 mm. (28.44 ins.) at 7:35 a. m. of the 24th. As the barograph did not work satisfactorily, we do not know just the exact barometric minimum.

Very probably the typhoon was formed near the Philippines on the 21st about 120 miles east of San Bernardino Strait or 80 miles to the east of northern Samar. It moved probably WNW. or NW. by W. at the beginning, then almost due west until it reached Daet. Fortunately, however, for Manila, after causing great destruction in Camarines Norte it took again a northwesterly direction, thus passing the center 30 or 40 miles to the NE. of Manila. At 6 a. m. of the 25th the typhoon was already in the China Sea to the W. of central Luzon.

The approximate positions of the center at 6 a. m. of the 24th, 25th and 26th were as follows:

June 24, 6 a. m., 123° 15′ long. E. 14° 05′ lat. N.
June 25, 6 a. m., 119° 05′ long. E. 16° 35′ lat. N.
June 26, 6 a. m., 113° 20′ long. E. 20° 05′ lat. N.

DETAILS OF THE WEATHER IN THE UNITED STATES

GENERAL CONDITIONS

A month of much stagnation in the movement of cyclones and anticyclones. The latter were fairly numerous for a summer month and apparently were offshoots from the North Pacific HIGH that first appeared in the Canadian Northwest or off the Washington and Oregon coasts. The usual details follow.

CYCLONES AND ANTICYCLONES

By W. P. DAY

The number of highs charted during the month was considerably above the normal, and a large majority were of the so-called Alberta type. However, these high-pressure waves could generally be traced back over the North Pacific Ocean, but moving in higher latitudes they first appeared on our daily charts over the Canadian Provinces of Alberta or Saskatchewan. Their oceanic origin was further indicated by a large lapse in temperature at relatively high levels (2,500–3,500 meters), whereas a more typical high from the Canadian interior shows, at this season at least, an underrunning wedge of cool air with a strong inversion at 2,000–2,500 meters.

There were few well-defined storm areas. Precipitation occurred mostly in troughs of low pressure in connection with the increased laspe rate produced by the advancing side of the high-pressure areas previously mentioned.

FREE-AIR SUMMARY

By V. E. JAKL, Meteorologist

The averages for the aerological stations given in Table 1 show that free-air temperatures over middle and eastern portions of the country ranged from somewhat below normal over the more northerly sections to about or slightly above normal at the most southerly stations. Approximately normal lapse rates prevailed, as shown by the fact that departures at all stations varied but slightly with altitude.

The departures in temperature show a fair correspondence with wind directions for the month. Wind resultants from kite (see Table 2) and pilot balloon observations show, within the range of altitudes for which temperature averages were obtained, that southwesterly and westerly winds were prevalent over Groesbeck and Due West, respectively, while elsewhere they were in

general northwesterly, particularly in the higher altitudes. This northerly component at the stations and levels concerned was moreover more pronounced than normal for the month.

The bearing of these resultant winds and temperature departures on the precipitation is apparent from the records. Over the southern States, where the trend of winds was from the southwest and west up to over 4,000 meters, the precipitation—except along the coasts—was apparently mostly of a local convectional nature, and over considerable portions was scanty. This was particularly true of Texas, where at Groesbeck, the most severe drought in years was experienced. Also at Due West, S. C., very little precipitation occurred after the 7th. On the other hand, at Broken Arrow, Okla., 300 miles north of Groesbeck, where the winds had a northerly component above 2,000 meters, precipitation was frequent and abundant. Broken Arrow was often under the influence of the moving highs and lows that affected the more northerly portions of the country, while Due West and Groesbeck, as usual for the time of year, were largely under the influence of more or less stagnant pressure conditions.

The local nature of much of the showery weather in the South is illustrated in a number of the free-air records. At Groesbeck, where most of the precipitation of the month occurred on the 1st, the pilot balloon record of the a. m. observation of that date, shows winds ranging from 1 m. p. s. on the ground to 8 m. p. s. at 7,000 meters, and at the p. m. observation no velocity exceeding 6 m. p. s. was recorded below 6,000 meters. At Due West, from the 5th to 7th, during which period most of the precipitation occurred, winds averaging less than 4 m. p. s. prevailed up to 9,000 meters. At Broken Arrow the precipitation also appears to have been of a local convectional nature on some days, as shown by the following kite record for the 13th, which was made a few hours before the occurrence of a thunderstorm accompanied by copious rainfall. It will be noted that there was light wind throughout the observed range of altitude, and a high lapse rate with gradually increasing humidity from the ground up to the level of incipient condensation (at 2,361 meters). The pressure was stationary during the observation.

Altitude, m. s. l.	Temperature	$\frac{\Delta t}{100m}$	Relative humidity	Wind direction	Wind velocity
Meters	° *C.*		*Per cent*		*M. p. s.*
233 (surface)	34.5		40	WSW.	4.5
1,612	19.7	1.07	82	W.	4.2
2,361	13.2	0.87	98	W.	6.2
3,109	7.8	0.72	82	WSW.	5.4
4,202	0.8	0.64	98	SW.	3.6

For comparison with a more northerly station the kite observation at Drexel on the 8th is also reproduced, and appears in the following table. This observation was followed in a few hours by a severe thunderstorm with over three inches of rainfall. For Drexel, which lay between a weak low on the south and a pronounced high on the northwest, the record shows a succession of strata having variable lapse rates and humidities, with no percentage of humidity approaching saturation except at the extreme upper limit, while the winds were fairly strong and the pressure fell rapidly. Broken Arrow, on the other hand, was in a region of ill-defined pressure distribution, and shows little of these conditions.

Altitude, m. s. l.	Temperature	$\frac{\Delta t}{100m}$	Relative humidity	Wind direction	Wind velocity
Meters	° *C.*		*Per cent*		*M. p. s.*
396 (surface)	34.8		51	SSE.	5.8
1,688	20.3	1.12	85	S.	10.0
2,064	20.9	0.16	29	S.	9.8
3,207	10.2	0.94	43	SSW.	10.0
4,664	−1.7	0.82	88	SSW.	7.8
5,017	−3.3	0.45	77	SSW.	8.1

While resultant winds showed the light velocities and small increase with altitude normal for the season, individual cases were observed where the increase in velocity with altitude was equal to any observed in the winter season. This was particularly so in numerous cases of so-called "nocturnal inversion" winds in the lower levels, in which light winds at the surface increased in the first few hundred meters to about 25 m. p. s., with no accompanying marked gradients in the sea level pressure.

In the midsummer months, with their prevailingly weak temperature gradients, a wind of nearly uniform direction but of no great velocity frequently extends to considerable heights. When occurring in connection with fairly well defined surface pressure distribution, these winds are often observed to prevail from the ground up, as at Ellendale on the 31st, when a two-theodolite pilot balloon observation made in front of a high showed due north wind of nearly uniform velocity up to 7,500 meters. With indifferent pressure this "solid" wind may begin at some distance aloft, as at Broken Arrow on the 24th and 25th, when two-theodolite observations showed winds veering from southerly to westerly to about 4,000 meters, and practically uniform northwesterly winds thereafter to 14,000 meters.

Easterly winds at high altitudes were occasionally observed early in the month as far north as Drexel and Washington. It was only at the most southerly stations, however, that they occurred frequently enough to show in the resultants. Key West had resultant easterly winds from the ground to the highest altitudes observed, while at Groesbeck there was a decided easterly component at 5,000 meters and above. A typical example of this frequent midsummer wind structure at Groesbeck is given in the two-theodolite observation of the 16th, which shows light winds changing from southerly to northerly with altitude to 3,500 meters, above which, moderate to strong winds from nearly due east prevailed up to 12,000 meters. On this date Groesbeck was some distance south of a strong high-pressure area.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressure during July, 1925*

TEMPERATURE (°C.)

Altitude m. s. l. meters	Broken Arrow, Okla. (233m.) Mean	Broken Arrow Departure from 7-yr. mean	Drexel, Nebr. (396m.) Mean	Drexel Departure from 10-yr. mean	Due West, S. C. (217m.) Mean	Due West Departure from 5-yr. mean	Ellendale, N. Dak. (444m.) Mean	Ellendale Departure from 8-yr. mean	Groesbeck, Tex. (141m.) Mean	Groesbeck Departure from 7-yr. mean	Royal Center, Ind. (225m.) Mean	Royal Center Departure from 8-yr. mean
Surface	26.8	−0.1	24.6	0.0	29.5	+2.2	20.3	−0.9	28.0	+1.1	24.1	−1.1
250	26.7	−0.1			29.0	+2.1			26.9	+1.0	23.7	−1.2
500	25.2	0.0	23.8	−0.2	25.8	+1.5	19.8	−1.1	24.6	+0.6	21.1	−1.3
750	24.4	+0.6	22.4	−0.3	23.8	+1.3	18.4	−1.2	23.5	+0.7	19.3	−1.2
1,000	23.2	+0.8	21.1	−0.2	22.1	+1.4	17.2	−1.2	22.9	+1.1	17.4	−1.3
1,250	21.7	+0.9	19.8	−0.1	20.2	+1.3	16.1	−1.2	22.0	+1.4	15.4	−1.6
1,500	20.1	+0.9	18.3	−0.1	18.3	+1.1	14.5	−1.6	20.7	+1.5	14.0	−1.4
2,000	16.8	+0.8	16.1	+0.7	14.5	+0.6	11.5	−1.9	17.7	+1.2	11.0	−1.6
2,500	13.5	+0.7	12.8	+0.6	10.6	−0.1	8.3	−2.1	14.8	+1.1	8.6	−1.3
3,000	10.2	+0.7	9.4	+0.5	6.8	−0.7	5.5	−2.0	11.6	+0.7	5.5	−1.4
3,500	7.2	+0.6	5.9	+0.4	3.7	−0.6	3.0	−1.6	8.5	+0.6	2.9	−1.1
4,000	4.0	+0.6	2.3	0.0	0.9	−0.6	0.2	−1.7	4.9	+0.2	−0.6	−1.8
4,500	1.4	+0.6	−1.5	−0.5			−2.0	−1.5				
5,000	−1.3	+0.6	−4.3	−0.7			−4.6	−1.4				

RELATIVE HUMIDITY (%)

Altitude m. s. l. meters	Broken Arrow Mean	Broken Arrow Departure	Drexel Mean	Drexel Departure	Due West Mean	Due West Departure	Ellendale Mean	Ellendale Departure	Groesbeck Mean	Groesbeck Departure	Royal Center Mean	Royal Center Departure
Surface	66	−3	60	−5	54	−11	65	−4	66	−7	64	+2
250	66	−3			54	−11			69	−5	64	+2
500	64	−2	59	−4	58	−9	64	−4	73	−2	66	+2
750	61	−4	58	−2	61	−8	61	−3	70	0	70	+4
1,000	59	−6	57	−2	62	−9	57	−4	60	−5	72	+5
1,250	60	−6	56	−2	63	−9	55	−4	53	−9	74	+7
1,500	62	−4	56	−2	64	−7	55	−2	52	−9	72	+5

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressure during July, 1925*—Continued

RELATIVE HUMIDITY (%)—Continued

Altitude m. s. l. meters	Broken Arrow, Okla. (233m.) Mean	Broken Arrow Departure from 7-yr. mean	Drexel, Nebr. (396m.) Mean	Drexel Departure from 10-yr. mean	Due West, S. C. (217m.) Mean	Due West Departure from 5-yr. mean	Ellendale, N. Dak. (444m.) Mean	Ellendale Departure from 8-yr. mean	Groesbeck, Tex. (141m.) Mean	Groesbeck Departure from 7-yr. mean	Royal Center, Ind. (225m.) Mean	Royal Center Departure from 8-yr. mean
2,000	65	0	48	−8	69	−2	52	−2	54	−5	71	+9
2,500	67	+3	51	−4	71	0	51	−1	55	−2	55	0
3,000	71	+8	50	−4	67	−2	48	−1	59	+3	53	+1
3,500	73	+11	53	−1	58	−7	45	−3	65	+8	54	+5
4,000	77	+15	59	+7	60	−1	43	−5	75	+16	56	+11
4,500	67	+11	86	+30			34	−15				
5,000	66	+8	86	+34			36	−10				

VAPOR PRESSURE (mb.)

Altitude m. s. l. meters	Broken Arrow Mean	Broken Arrow Departure	Drexel Mean	Drexel Departure	Due West Mean	Due West Departure	Ellendale Mean	Ellendale Departure	Groesbeck Mean	Groesbeck Departure	Royal Center Mean	Royal Center Departure
Surface	22.92	−1.07	18.69	−1.16	21.05	−1.69	15.62	−1.63	24.47	−0.94	19.68	−0.15
250	22.85	−0.94			20.76	−1.62			23.96	−0.54	19.29	−0.25
500	20.44	−0.42	17.57	−1.24	18.61	−1.33	14.91	−1.75	22.23	+0.07	17.07	−0.19
750	18.63	−0.10	15.58	−1.03	17.37	−1.05	13.00	−1.39	19.75	+0.40	16.12	+0.41
1,000	16.84	−0.22	14.17	−0.91	16.04	−0.99	11.08	−1.72	16.19	−0.57	14.72	+0.31
1,250	15.53	−0.06	12.90	−0.81	14.67	−1.02	9.83	−1.62	13.52	−1.29	13.44	+0.43
1,500	14.43	+0.31	11.67	−0.68	13.53	−0.51	8.91	−1.30	12.29	−1.13	11.76	+0.14
2,000	12.41	+1.04	8.77	−1.08	11.75	+0.25	6.82	−1.38	10.59	−0.59	9.35	+0.51
2,500	10.56	+1.44	7.61	−0.24	9.55	+0.23	5.47	−1.21	9.11	−0.10	6.28	−0.18
3,000	9.06	+1.78	6.48	+0.29	7.22	−0.17	4.48	−0.86	7.96	+0.21	5.43	+0.36
3,500	7.60	+1.69	5.76	+0.85	5.27	−0.24	3.70	−0.74	7.62	+1.05	5.16	+1.14
4,000	6.36	+1.83	5.38	+1.48	4.65	+0.42	2.90	−0.75	7.64	+2.00	4.38	+1.27
4,500	4.96	+1.66	5.95	+2.61			1.92	−1.32				
5,000	4.69	+1.63	5.05	+2.50			1.72	−1.19				

TABLE 2.—*Free-air resultant winds (m. p. s.) during July, 1925*

Altitude, m. s. l. (meters)	Broken Arrow, Okla. (233 meters) Mean Dir.	Mean Vel.	7-year mean Dir.	7-year mean Vel.	Drexel, Nebr. (396 meters) Mean Dir.	Mean Vel.	10-year mean Dir.	10-year mean Vel.
Surface	S. 16°E.	2.3	S. 2°E.	3.0	S. 50°W.	0.7	S. 3°W.	2.0
250	S. 14°E.	2.4	S. 2°E.	3.2				
500	S. 10°W.	4.0	S. 11°W.	4.6	S. 31°W.	0.9	S. 4°W.	2.9
750	S. 24°W.	4.7	S. 20°W.	5.0	S. 66°W.	1.8	S. 18°W.	3.9
1,000	S. 31°W.	4.4	S. 27°W.	4.8	S. 83°W.	2.4	S. 26°W.	4.3
1,250	S. 42°W.	4.0	S. 32°W.	4.6	N. 88°W.	3.0	S. 38°W.	4.4
1,500	S. 55°W.	3.8	S. 37°W.	4.5	N. 80°W.	4.5	S. 47°W.	4.4
2,000	S. 79°W.	2.6	S. 41°W.	3.6	N. 81°W.	5.0	S. 58°W.	4.9
2,500	W.	3.2	S. 52°W.	3.8	N. 78°W.	6.0	S. 73°W.	5.5
3,000	W.	3.0	S. 62°W.	4.3	N. 70°W.	6.3	S. 74°W.	6.2
3,500	N. 75°W.	5.4	S. 69°W.	2.9	N. 67°W.	8.2	S. 77°W.	7.1
4,000	N. 59°W.	6.9	S. 74°W.	6.7	N. 74°W.	9.7	S. 80°W.	7.6
4,500	N. 55°W.	12.8	S. 66°W.	8.6	S. 78°W.	7.9	S. 66°W.	7.7
5,000	N. 45°W.	15.0	S. 30°W.	4.5	S. 22°W.	8.1	S. 55°W.	8.4

Altitude, m. s. l. (meters)	Due West, S. C. (217 meters) Mean Dir.	Mean Vel.	5-year mean Dir.	5-year mean Vel.	Ellendale, N. Dak. (444 meters) Mean Dir.	Mean Vel.	8-year mean Dir.	8-year mean Vel.
Surface	S. 71°W.	2.5	S. 67°W.	1.3	N. 14°W.	2.5	N. 19°W.	0.1
250	S. 70°W.	2.7	S. 69°W.	1.4				
500	S. 76°W.	3.1	S. 78°W.	2.0	N. 19°W.	2.8	S. 7°W.	.2
750	S. 80°W.	3.3	S. 85°W.	2.4	N. 39°W.	2.6	S. 22°W.	1.1
1,000	W.	3.6	S. 88°W.	2.7	N. 44°W.	3.1	S. 50°W.	1.7
1,250	N. 89°W.	4.7	S. 86°W.	3.0	N. 69°W.	3.0	S. 60°W.	2.2
1,500	N. 85°W.	6.1	S. 87°W.	4.3	N. 54°W.	4.5	S. 72°W.	2.9
2,000	N. 78°W.	7.6	S. 88°W.	5.6	N. 49°W.	5.4	S. 87°W.	4.2
2,500	N. 73°W.	9.5	N. 88°W.	6.4	N. 56°W.	7.2	N. 84°W.	6.0
3,000	S. 87°W.	11.3	S. 86°W.	7.9	N. 52°W.	8.7	N. 82°W.	7.6
3,500	N. 67°W.	10.1	N. 85°W.	7.5	N. 57°W.	11.8	N. 74°W.	9.9
4,000	N. 89°W.	11.4	N. 81°W.	8.4	N. 56°W.	12.9	N. 68°W.	11.2
4,500					N. 61°W.	13.2	N. 63°W.	13.2
5,000					N. 83°W.	14.2	N. 73°W.	15.3

Altitude, m. s. l. (meters)	Groesbeck, Tex. (141 meters) Mean Dir.	Mean Vel.	7-year mean Dir.	7-year mean Vel.	Royal Center, Ind. (225 meters) Mean Dir.	Mean Vel.	8-year mean Dir.	8-year mean Vel.
Surface	S. 33°W.	5.5	S. 21°W.	3.6	S. 84°W.	1.9	S. 80°W.	1.7
250	S. 31°W.	6.6	S. 22°W.	4.4	S. 81°W.	1.9	S. 80°W.	1.8
500	S. 37°W.	8.4	S. 30°W.	6.2	N. 87°W.	4.1	S. 76°W.	3.3
750	S. 36°W.	8.6	S. 30°W.	6.3	N. 83°W.	5.2	S. 76°W.	4.2
1,000	S. 32°W.	8.1	S. 30°W.	6.0	N. 79°W.	6.6	S. 80°W.	4.8
1,250	S. 30°W.	6.7	S. 31°W.	5.4	N. 86°W.	6.8	S. 81°W.	5.5
1,500	S. 26°W.	5.6	S. 31°W.	4.9	N. 84°W.	8.5	S. 86°W.	6.2
2,000	S. 23°W.	4.2	S. 30°W.	4.0	N. 80°W.	9.1	S. 88°W.	7.3
2,500	S. 7°W.	4.0	S. 27°W.	3.6	N. 73°W.	11.8	N. 87°W.	9.6
3,000	S. 9°W.	5.3	S. 22°W.	3.7	N. 78°W.	8.5	S. 89°W.	11.2
3,500	S. 8°W.	7.4	S. 15°W.	2.4	N. 76°W.	9.2	S. 87°W.	10.7
4,000	S. 45°W.	8.0	N. 83°W.	1.1	N. 61°W.	9.7	N. 70°W.	9.5
4,500	S. 45°W.	7.0	N. 18°E.	3.6	N. 45°W.	10.0	N. 46°W.	8.4
5,000								

THE WEATHER ELEMENTS

By P. C. DAY In Charge of Division

PRESSURE AND WINDS

The distinctive feature of the atmospheric pressure during July was the persistence of anticyclonic conditions, which produced, however, in different portions of the month almost opposite effects upon the weather over large areas of the country.

During the first half of the month anticyclones had their origin mainly over the western interior and moved slowly eastward over the Central and Southern States. This distribution favored warm weather over most of the country from the Rocky Mountains eastward, with frequent thundershowers and local high winds, particularly over the Central States, from the 12th to the 16th.

Beginning with the middle of the month and continuing until the close, anticyclones entered the United States at frequent intervals from the Canadian Northwest, and, moving eastward mainly over the Northern States, favored changes to cooler weather over all northern and central districts. During this period showers still prevailed in many northern and central districts, and local high winds were rather frequent, particularly about the 24th to the 26th from the middle plains eastward to Pennsylvania and Maryland.

The cyclones were of the ordinary summer type, though fewer in number and mainly less well defined than usual. No single cyclone materially influenced precipitation over any extensive path, save in a few cases along the northern border, and on the 26th to 28th when a low pressure area moved along the coast from North Carolina, passing east of New England attended by moderate to locally heavy rains.

The average barometric pressure was relatively high over the Gulf and South Atlantic Coast States, and in the upper Missouri Valley and the far Northwest, and relatively low over the Canadian Maritime Provinces, and the far Southwest.

Average pressures were below normal over the greater part of the country from the Mississippi Valley eastward, the largest deficiencies occurring from the southern Appalachian Mountains northward to Ontario.

From the Great Plains westward to the Pacific the average pressure was mainly above normal, the largest excesses appearing over the central Rocky Mountains and northern Great Plains.

Pressure was higher than during June over all central and western districts of both the United States and Canada, and lower over the eastern third of both countries, a condition not unusual, except that the positive changes from June to July in the Great Plains and Rocky Mountain regions and the negative changes in eastern districts were both materially larger than usual.

The prevailing winds were mainly southerly from the middle and southern Plains eastward to the Atlantic coast and thence northward to New England, also over much of the Ohio Valley and lower Lake regions.

From the Dakotas eastward to the upper Lakes the prevailing winds were mainly from northerly points. Elsewhere they were variable. The details of the more important storms of the month follow at the end of this section.

TEMPERATURE

The first two weeks of July, 1925, were hot over the greater part of the country, save during the first week in parts of the Southwest, from the upper Lakes to New England, and over the north Pacific coast. The second week was particularly warm in the central valleys, Great Plains and northern Plateau regions, where weekly means ranged from 5° to 10° above normal, and maximum temperatures were above 100° at many points in the Great Plains and Southwest.

During the third week temperatures continued high from the Rocky Mountains westward, and over the Southern Great Plains, where the weekly means ranged up to 10° above normal, and maximum temperatures were frequently above 100°. From the Missouri and middle Mississippi Valleys eastward this week brought much-needed relief from the severe heat of the preceding weeks and the weekly averages were mainly lower than normal.

The last decade experienced important and gratifying changes in temperature, the period as a whole averaging mainly cooler than normal over the middle and northern sections, and moderately warmer than normal in the more southerly sections. The month as a whole was moderately warmer than is usual in July over the entire southern half of the country, and from the central Plains and northern Rocky Mountains westward to the Pacific except in extreme northwest Washington.

In the southern Appalachian Mountain regions, the southern Plains States, and from Nevada and Utah northward to Idaho and eastern Washington the month was decidedly warm.

From the Dakotas and upper Mississippi Valley eastward to the Ohio Valley and Northeastern States, there was much delightfully cool weather, the monthly averages being below normal, and materially so from the lower Lakes to New England.

In a few sections, notably in the western parts of the Carolinas, in northern Georgia, and in portions of the northern Plateau regions and in southern California the monthly means of temperature were among the highest on record.

In a number of the Northwestern States July makes the seventh consecutive month with average temperatures above normal.

Maximum temperatures were 100 or above at some time during the month in all the States, save New England, New Jersey, and Wisconsin. They were above 120° at points in Arizona and California, and 110° or above in practically all other States from and including the Great Plains westward. At numerous points west of the Rocky Mountains and over the southern Great Plains the maximum temperatures were the highest of record for July, and locally in California, Arizona and some other western sections they were the highest ever observed. In portions of California the unusual heat near the middle of the month caused several deaths, many prostrations, some damage to fruits and vegetables, and a general suspension of activities.

The warmest days were mainly during the first week from the Mississippi River eastward, except in the Gulf States, and about the middle of the month in the lower Mississippi Valley and from the Great Plains westward, except in Oregon and Washington where the warmest weather occurred on the 31st.

Minimum temperatures were at or near the freezing point on several occasions during the last decade in the more northern States and at exposed points in both the eastern and western mountain districts, and light frosts were observed as far south as northwestern Nebraska.

At Duluth, Minn., the minimum temperature on the 29th was the lowest of record for July, and the nights were unseasonably cool during much of the latter part of the month in the Northeastern States.

PRECIPITATION

Precipitation for the country as a whole was more or less scanty, and while considerable areas had more than the normal fall, these in the main comprised States with large surface areas but having normally only small amounts of precipitation in July, and hence the total precipitation deposited during the month was far less than normal. The deficiencies in the monthly totals were large over the south Atlantic and portions of the East Gulf States, notably in the Carolinas, northern Georgia, southern Florida and much of Tennessee. Texas had a large deficiency over the central and eastern districts, and precipitation was generally deficient to a considerable extent in the eastern Great Plains, the middle and upper Mississippi Valley, the upper Missouri Valley and the far Northwest.

There was a substantial excess of precipitation over New Jersey, much of Pennsylvania and New York, and generally over southern and northwestern New England. Otherwise than as noted it was mainly not far from normal save in a few small areas.

Generally speaking, precipitation was well distributed through the month over the areas where considerable amounts usually fall, thus in a way mitigating the harmful effect in localities where the falls were less than normal. The moderately cool weather during the latter half of the month over most central and eastern districts also lessened evaporation, compensating in some degree the deficiency in precipitation.

Some unusually heavy rains occurred, notably in the vicinity of Dubuque, Iowa, on the 3d and 4th, causing

damage amounting to $50,000 or more, also at Detroit, Mich., on the night of July 31–August 1, where much damage resulted from flooding.

The total fall was unusually heavy in portions of Pennsylvania; Nevada as a whole, had the second wettest July of record. On the other hand the monthly amounts in the Carolinas and Georgia were the least of record, or among the least, for July, in a period of nearly 50 years.

At the end of the month severe drought existed in the southern Appalachian region, and the lack of water for power and other purposes was becoming acute. In parts of western and northern Louisiana, and over much of Texas, drought has continued for many months, and the high temperature and excessive sunshine greatly intensified the injurious effects of deficient soil moisture.

SNOWFALL

As far as reports received indicate, no snow fell except at a few points in the high mountains of Colorado.

RELATIVE HUMIDITY

Over the greater part of the country relative humidity was less than normal, the deficiencies being large south of the Ohio River, in the area between the Mississippi River and the Rocky Mountains, and over most of the far Northwest. In portions of Washington it was abnormally low on the 18th and 19th when values of only 4 or 5 per cent were reported at several points.

There were moderate excesses generally from the upper Mississippi Valley eastward, and over the middle and southern Rocky Mountain and Plateau regions, and locally over the Pacific Coast States.

SEVERE LOCAL WIND AND HAIL STORMS, JULY, 1925

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards)[1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Pocatello, Idaho	1	P. m.				Thunderstorm and hail.	Streets flooded; 2 horses killed.	Official, U. S. Weather Bureau.
Salt Lake City, Utah (vicinity of).	1			1		Thunderstorm	Considerable property damage	Do.
Chattanooga, Tenn., and vicinity.	3	12.55 p. m.				Thunderstorm and rain.	Some trees damaged, others blown down; telephone service crippled.	Chattanooga Times.
Thomaston, Ga. (5 miles west of).	3	3.30 p. m.	880–1,760		$14,000	Moderate hail and wind.	Loss to peaches over path 2 miles long; other minor damage.	Official, U. S. Weather Bureau.
Benton County, Iowa	3	4.30 p. m.				Hail	Crop loss about 25 per cent	Do.
Dubuque, Iowa	3	5 p. m.			50,000	Wind and heavy rain.	Extensive damage to buildings; trees blown down; basements flooded; traffic obstructed.	Do.
Rockford, Ill	3	5.45 p. m.	1,760		5,000	Thundersquall	Roofs, windows, and trees damaged; 2 persons injured.	Do.
Brooklyn, Wis	3	6.30 p. m.	1,760		1,000	Wind	Damage principally to silos and poles	Do.
Between Belleville and Monticello, Wis.	3	P. m.				Violent wind	Farm buildings, wires, trees, and shrubbery damaged.	Capital Times (Madison, Wis.).
Hazelhurst, Ga	3					High wind	Schoolhouse, trees, and poles blown down	Official, U. S. Weather Bureau.
Scottsville, Kans	4	1–2 a. m.	440			Heavy hail	Crops injured	Do.
Between Pocatello and Mink Creek, Idaho.	4	Noon				Tornado	Cloud moved northward; did not reach ground; observed 20 minutes.	Do.
Jackson, Tenn. (near)	4					Wind	Barn blown down; trees uprooted	Do.
Greenville, S. C., and vicinity.	4	2.15 p. m.		1	2,000	Thunderstorm and hail.	Crops damaged in small area; about 200 telephones out of order.	Greenville News (S. C.).
Wichita, Kans. (near)	6	3 p. m.	440		2,000	Violent wind	Path 1 mile long	Official, U. S. Weather Bureau.
Eastern Cherry and northwestern Brown Counties, Nebr.	6	4.45–5 p.m.	300–500			Hail	Windows broken, roofs damaged, and crops more or less harmed over small area.	Do.
Washington County, Md	6	5 p. m.			2,000	Thundergust	One building demolished, several damaged; trees uprooted; fences blown down.	Do.
Cherokee, Jasper, Johnson, and Appanoose Counties, Iowa.	6	8 or 9 p. m.	4–6 mi.		150,000	Wind and hail	Crop loss estimated at 80 per cent. Heavy property damage.	Do.
Dysart, Iowa, and vicinity	6	P. m.				Hail	Considerable crop loss reported	Do.
McPherson County, Kans	6	P. m.		1		Violent wind	Damage principally to telephone lines and out buildings on farms.	Do.
Paducah, Tex. (near)	7	4 p. m.	50		12,000	Small tornado	Houses and farm property damaged. One person injured.	Do.
Windsor, Conn	7				25,000	Thunderstorm and hail.	Tobacco and corn crops injured, 500 acres hail cut. Minor property damage.	Do.
Woodbury County, Iowa	8	4 p. m.	880		10,000	Hail	Heavy crop damage; no other losses reported	Do.
Cherokee County, Iowa	8	7 p. m.	3 mi.		75,000	Wind and hail	Heavy crop loss; many buildings and windmills damaged; poles split.	Do.
Kent County, Del. (north part of).	8	7 p. m.				Heavy hail	Severe crop damage	Do.
Marathon County, Wis	8	7–7.45 p.m.	2½ mi		75,000	Heavy hail and wind.	Farm buildings and crops extensively damaged.	Do.
Lakota, Iowa	8	P. m.				Wind	Two homes wrecked; wires blown down and trees prostrated; much crop loss; 5 persons injured.	Do.
Minneapolis-St. Paul and vicinity, Minn.	8	P. m.		4		Tornadic wind, rain and hail.	Buildings damaged; basements flooded and crops injured by hail; 18 persons injured.	Pioneer (St. Paul, Minn.).
Whiting, Iowa	8	P. m.	3 mi.			Hail	Damage over path about 10 miles long estimated at 50 per cent.	Official, United States Weather Bureau.
Webster City to Fort Dodge, Iowa.	8	P. m.				Wind	Telephone poles leveled; small buildings blown over; crops flattened.	Do.
Blanca, Colo	9	2.30–3 p.m.			15,000	Hail	Head lettuce and other crops destroyed; many windows broken.	Do.
Western, N. Y	10	A. m.			30,000	Electrical and rain.	Several farm buildings struck by lightning causing loss of stock, hay, wheat and some farm machinery.	Democrat Chronicle (Rochester, N. Y.).
Millen, Ga	11	3 p. m.				Thunderstorm, wind and hail.	Some trees uprooted; house struck by lightning and burned.	Official, United States Weather Bureau.
Sturgeon Bay, Wis	11	4 p. m.		1		Tornadic wind	Several buildings in business section damaged; 2 persons injured.	Press Gazette (Green Bay, Wis.).
Lane, Mont. (near)	12		1 mi.			Wind and hail	Crops damaged; several small buildings destroyed.	Record-Herald (Helena, Mont.).

[1] Mi. signifies miles, instead of yards.

Severe local wind and hail storms, July, 1925—**Continued**

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Clayton County, Iowa	12	1 a. m.				Wind and hail	Crops damaged about 30 per cent.	Official, United States Weather Bureau.
Jones County, Iowa	12	2 a. m.				do	Crops damaged about 60 per cent; other damage considerable.	Do.
Galesburg, Ill. (vicinity of)	12	4-4.30 a.m.	3 mi.			do	Crops prostrated; trees torn up	Do.
Southeast Cecil and northeast Kent Counties, Md.	12	2 p. m.	1-4 mi.		$20,000	Heavy hail	Corn and tomato crops nearly total loss on four farms; crops on 20 farms damaged 20 to 75 per cent.	Do.
Washington, D. C. (southeastern Potomac Park).	12	2.30 p. m.				Strong wind	About 12 large willows uprooted or broken off and many others damaged at Hains Point; 4 autos damaged; 1 person injured.	Do.
Anne Arundel County, Md.	12				10,000	Electrical	Warehouse and contents of Camp Meade Salvage Co. destroyed.	Do.
Indianapolis, Ind., and vicinity.	12	P. m.			500,000	Severe thunderstorm and wind.	Street car and telephone service paralyzed; windows shattered; much crop damage.	Indianapolis (Ind.) Star.
Lyon County, Iowa	13	2:30 and 9 p. m.	1-3 mi.		25,000	Wind and hail	Damage principally to crops	Official, United States Weather Bureau.
Nashville, Tenn., and vicinity.	13	2-3 p. m.	880-1,760		6,000	Hail	Greenhouses and truck crops damaged. Path 13 miles long.	Do.
Linton, Tenn	13	4 p. m.		2		Wind	Large limb blown down onto tent. Others hurt.	Do.
Franklin, Wake, Nash, Durham, and Stokes Counties, N. C.	13	P. m.	2-3 mi.			Heavy hail	Cotton, corn, and tobacco seriously damaged over 20-mile track; on several farms crops almost entirely destroyed.	Do.
Macon, Ga	13	6:40 p. m.				Electrical and wind.	Chimneys blown over; wires down; one house struck by lightning.	Do.
Driftwood, Okla., and vicinity.	13					Tornado	Almost every building in town wrecked; 1 person injured; stock suffered.	Wichita (Kans.) Eagle.
Yankton, S. Dak., and vicinity.	13	8:18 p. m.			10,000	Severe thunderstorm.	Several roofs blown off; plate glass window shattered; trees and cornfields flattened.	Official, United States Weather Bureau.
Mobile, Ala	13					Thunderstorm and wind.	Sign, smokestack and some poles blown down.	Do.
Farmersville, Tex	14	5:30 p. m.		1	10,000	Tornado	Two persons injured; damage to crops and buildings. Storm moved to southeast.	Do.
Grand Haven, Mich. (near)	14-15					Thunderstorm	One home struck by lightning; 1 person injured.	Do.
Sierra Nevada Mountains, northeast of Fresno, Calif.	14-15			1		Electrical, wind and rain.	A score of fires started by lightning; 8 persons injured and many cabins damaged by falling trees.	Morning Republican (Fresno, Calif.).
Holland, Mich., and vicinity.	15	A. m.				Wind	One barn wrecked; trees uprooted; windows shattered.	Grand Rapids Press (Mich.).
Wright and Hancock Counties, Iowa.	15	7 p. m.	1,760		100,000	Wind and hail	Corn and oat crops suffer most; barns and small buildings demolished.	Official, United States Weather Bureau.
Escanaba, Mich., and vicinity.	15	7 p. m.	20-30 mi.		50,000	Tornadic wind	Two barns wrecked and several buildings damaged; trees and poles prostrated; highways obstructed; crops and orchards injured.	Do.
Sentinal and Casa Grande, Ariz.	15					Electrical and wind.	Character of damage not reported	Do.
Baltimore County, Md. (north part of).	15				58,881	Thunderstorm acpanied by heavy rain.	Road beds and bridges badly washed; crops injured and cellars flooded.	Do.
Biglerville, Pa	16	12.30-4 p. m.				Thunderstorm with heavy rain.	Fields flooded; no other damage reported	Do.
Elmira, N. Y., and vicinity.	16	2-3 p. m.				Electrical and wind.	Loss to telephone and electric light companies heavy.	Star Gazette (Elmira, N. Y.).
Northern New York	16			2		Electrical, wind, and rain.	Telephone and light services crippled; trees and crops damaged.	Star (Oneonta, N. Y.).
Venango, Crawford, and Mercer Counties, Pa.	16			1		Electrical and wind.	Severe damage to crops; cattle killed; traffic impeded by fallen trees.	Pittsburgh Gazette Times (Pa.).
Elk and McKean Counties, Pa.	16					do	Barn demolished; other buildings unroofed; much damage to crops.	Do.
Washington County, Pa	16			1		do	Several cows killed; considerable injury to buildings.	Do.
Pittsburgh, Pa	16	3.30 p. m.		4		Thunderstorm	Considerable property damage; much traffic delay.	Official, United States Weather Bureau.
Lebanon, Lancaster, and Berks Counties, Pa.	16	4-7 p. m.			100,000	Thunderstorms, hail and wind.	Barns struck by lightning and destroyed; other damage; 12 militiamen injured by lightning.	Do.
Riverside, N. J., and vicinity.	16	10 p. m.			250,000	Wind	Enormous loss in orchards; highway for 2 miles blocked by fallen trees; several persons hurt by flying glass.	Do.
Helena, Mont	17	6.15 p. m.			20,000	do	Large circus tent torn to shreds	Official, United States Weather Bureau; Record-Herald (Helena, Mont.).
San Luis Obispo, Calif. (vicinity of).	17	P. m.				Series of thunderstorms.	Several fires started by lightning; grain fields burned; garage and service station damaged.	Official, United States Weather Bureau.
Fresno, Calif.	17					Thunderstorm and wind.	Grain field fired; old building wrecked; oak trees uprooted.	Do.
Stevens County, Kans	18	3 p. m.				Heavy hail and high wind.	Crops greatly injured in path of storm; small buildings damaged.	Do.
Waxahachie, Tex. (near)	18	5.30 p. m.	1,320		5,000	Tornado	Path 3 miles long; slight damage as area covered was sparsely settled; 5 persons injured.	Dallas Morning News.
Hardin County, Iowa	19	6 p. m.				Wind and hail	Considerable crop damage, especially to corn; 3 barns demolished.	Official, United States Weather Bureau.
Salt Lake City, Utah	19			1		Electrical	Considerable property damage	Do.
Mobile, Ala	19			1		do	One residence damaged	Do.
Holland and Zeeland, Mich.	19-20				5,000	Thunderstorm	One home destroyed	Do.
Berne, Ind. (near)	20					Heavy hail	Oats and corn much damaged	Do.
Twin Falls, Idaho, and vicinity.	21	P. m.			200,000	Wind, rain, and hail.	Trees uprooted; windows broken; basements flooded.	Tribune (Pocatello, Idaho).
Pocatello, Idaho (3½ miles north of).	21		3,520		15,000	Severe hail	Crops beaten down	Official, United States Weather Bureau.
Grand Junction, Colo	21				15,000	High wind	Pear orchards considerably damaged	Do.
Pocatello, Idaho (4 to 6 miles south of).	22		880-1,760		8,000	Wind, rain, and hail.	Heavy damage on a few farms	Tribune (Pocatello, Idaho).
Western Massachusetts	22					Wind, electrical, and rain.	Widespread crop damage; barns torn from foundations; several fires started and much damage to highways and buildings.	Watertown Times (N. Y.).
Wilmington, N. C	23	A. m.		1		Thunderstorm	Some loss caused by lightning	Official, United States Weather Bureau.
Buckhorn, Wyo	23	5-6 p. m.	2,200		1,000	Heavy hail	Wheat, oats, and potatoes badly damaged	Official, United States Weather Bureau.

Severe local wind and hail storms, July, 1925—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Scott County, Iowa	24	2 p. m.			$225,000	Tornado, wind, and hail.	Extensive damage to crops and buildings. Tornado was confied to Blue Grass Township only.	Do.
Cedar County, Iowa	24	3 or 4 p. m.	3 mi.		100,000	Hail	Severe crop loss	Do.
Henry County, Iowa	24		3,520			Wind and hail	Corn and oats severely damaged; many windows broken; poultry killed.	Do.
Eastern Washington	24					Wind	Fruit blown off	Do.
Spencer, Wyo.	24	5-6 p. m.	3,520		6,000	Heavy hail	Crops total loss in places; several buildings damaged.	Do.
Tampa, Fla. (4 mi. west of)	24	5:45 p. m.	20		20,000	Tornado	Two houses destroyed; 2 garages damaged and 1 demolished; other minor damage. Path 300 yards long.	Do.
Republic County, Kans.	24	7:30-8 p.m.	2-3 mi.		10,000	Severe hail	Much damage to crops	Do.
Lake County, Ill. (north part of).	24	11 p. m.	440			Wind	Small buildings overturned; apple trees damaged; poles down.	Do.
Henry, Knox, Mercer, Rock Island, and Warren Counties, Ill.	24	P. m.	½-5 mi.		400,000	Wind and hail	Damage principally to corn crop. One person injured.	Do.
Bond County, Ill.	25	12:40 p. m.	1,760		4,500	do	Crops and windows damaged	Do.
Johnson County, Iowa	25	3 p. m.				do	Considerable crops damage in places; some glass broken.	Do.
Linwood, N. Y., and vicinity	25	4 p. m.	3 mi.		250,000	Heavy hail	Corn, beans, fruits, wheat, and barley badly damaged. Path 15 mile long.	Do.
Jefferson and Henry Counties, Ky.	25					Wind	Roofs, wire systems, and timber damaged	Do.
Shelby County, Ohio	25	4 p. m.	3½ mi.	1	750,000	do	Chautauqua tent collapsed burying about 1,200 people and injuring 30. Heavy losses sustained by farmers and public utilities companies.	Sidney Daily News (Ohio).
McPherson County, Kans	25	P. m.				Tornado	Total damage not great	Official, United States Weather Bureau.
Fairfield County, Ohio	25	P. m.			500,000	Tornadic wind	Corn crop severely damaged	Do.
Evansville, Ind., and vicinity	25					Thunderstorm and wind.	Overhead wires, cornices, chimneys, and signs damaged; some corn blown down.	Do.
Lebanon, Colebrook, and Mount Gretna, Pa.	25		2 mi.		1,000,000	Thunderstorm and downpour.	Railroads washed out; mines flooded; crops washed away. Several hurt by lightning.	Do.
Jefferson County, N. Y	25-26				35,000	Electrical and rain.	Wire communication interrupted; buildings on one farm burned.	Watertown Times (N. Y.).
Powershiek County, Iowa	26	1-2 a. m.	880-2,640			Hail	Corn badly shredded; garden truck ruined	Official, United States Weather Bureau.
Union Bridge, Md. (½ mi. south of).	26	3.30 p. m.	880		5,000	Thunderstorm and hail.	Crops injured	Do.
Beltsville, Md	26	4 p. m.	880-1,760		13,000	do	Grapes, cantaloupes, and mellons damaged; poles blown down; farm machinery damaged.	Do.
Nansemond, Va.	26	4 p. m.				Tornado	Considerable property and crop damage; several persons injured.	Do.
Sumter, S. C.	26	P. m.			7,000	Thunderstorm, squall, and hail.	Details not reported	Do.
Alden, Iowa (west of)	26	7 p. m.	2½-3 mi.		25,000	Wind and hail	Three barns demolished; crop loss considerable over path 6 miles long.	Do.
Harrold, S. Dak. (west of)	26	7 p. m.	1,760			Hail	Corn damaged 50 to 100 per cent and flax 35 per cent.	Capital Journal (Pierre, S. Dak.).
Circle, Mont. (near)	26					Wind	Buildings unroofed	Record-Herald (Helena, Mont.).
Mildred, Mont. (west of)	26		2 mi.			Wind and hail	Much standing grain totally destroyed; trees broken; buildings demolished. Two persons injured.	Official, United States Weather Bureau.
Winneshiek County, Iowa	26	8 p. m.	3 mi.			do	Crops damaged from 10 to 80 per cent; 1 silo and several windmills blown down.	Official United States Weather Bureau.
Fayette County, Iowa	26	9 p. m.				do	Damage chiefly by wind; many cornfields total loss, others damaged about 50 per cent. A number of buildings damaged.	Do.
Gilbert, Iowa	26	10 p. m.				do	Trees and wires down; corn foliage shredded over wide area.	Do.
Le Roy, Colo	26	11.30 p. m.	2,640		4,000	Hail	Grain crops and gardens destroyed; trees injured; windows broken.	Do.
Loveland, Colo. (near)	28	Night				Hail	Crops on one farm beaten into ground	Do.
Brown and Oconto Counties, Wis.	29	11 a. m.-1 p. m.	880-3,520		5,000	Heavy hail	Corn and oats damaged	Do.
Marshall, Wyo.	29	3.30-4.50 p. m.	3 mi.		3,000	do	Gardens and 50 per cent of grains ruined	Do.
Iola, Kans	29	6.45 p. m.		1	4,000	Violent wind	Roof of store torn off and small building blown over; several fires started by lightning; 2 persons injured.	Topeka Daily Capital (Kans.).
Dodge City, Kans. (near)	29	p. m.	4 mi.			Electrical, rain, hail.	All crops in path of hail ruined; livestock killed.	Official, United States Weather Bureau.
Deerlodge and Powell Counties, Mont. (parts of).	29					Hail, wind, and rain.	Crops injured; poultry killed; roads damaged	Record-Herald (Helena, Mont.).
Vernon County, Wis. (central part).	30	2 a. m.	880		1,000	Moderate hail	Tobacco crop damaged	Official, United States Weather Bureau.
Dodson, La	30	6 p. m.	100		4,000	Tornado	Houses and barns blown down or damaged; path 1,000 yards long.	Do.
Richland, Tex	30	8 p. m.	880		100,000	do	Damage mainly to buildings and oil-field property; 1 person hurt. Storm moved to southeast.	Do.
Caroline, Queen Anne, and Talbot Counties, Md.	31				2,650	Rain	Roadbed washed out; fields inundated by breaking of dam; 3 bridges washed away.	Do.
Mobile, Ala., and vicinity	31				2,100	Thunderstorm	Telephone and other wire systems damaged and window panes broken.	Do.

STORMS AND WEATHER WARNINGS

WASHINGTON FORECAST DISTRICT

The month was very quiet as far as storm warnings were concerned. Small-craft warnings were issued on the 16th, 22d, 27th, and 31st for portions of the middle and north Atlantic coast and storm warnings on the evening of the 31st from New Haven to Eastport. The month was characterized by a considerable number of Alberta highs.—*R. H. Weightman.*

CHICAGO FORECAST DISTRICT

The weather in this district was rather warm during the first half of July and cool during the second half; and the month, as a whole, averaged below normal in temperature, except in the extreme western portion of the region.

Rainfall, for the most part, was deficient, and decidedly so in some areas, especially from the Valley of the Red River of the North southward across the middle and lower Missouri Valleys. On the other hand, copious rainfall occurred in portions of the lower Michigan peninsula and the middle upper Mississippi Valley. Weather conditions were not such as to call for general warnings, and only minor advices in the nature of small-craft warnings on the Great Lakes and frost warnings for the cranberry marshes of Wisconsin were sent out on a few occasions.

In addition to the regular forecasts, special forecasts were made for the forest interests of western Montana and for the fruit spraying interests of southwestern lower Michigan and Door County, Wis.

The forecaster was called upon on two different occasions to make special predictions which seem worthy of note:

1. For the Chicago-Mackinac Island cruiser race.
2. Flying weather for night flight of six Army airplanes en route from Cheyenne to Chicago.

The cruiser race started from Chicago on the afternoon of Saturday, July 25, there being about 20 entries, sloops, schooners, and yawls; and on the morning of that day a special winds and weather forecast was made covering the course down Lake Michigan for the period ending Monday night, and special forecasts twice daily thereafter until the morning of the 28th. The forecast was for northerly winds following the time of the start, probably becoming fresh, and forecasts for continued head winds were made in the later issues. These were broadcast widely by radio, so that boats equipped with receiving sets might pick them up during the race. In consequence of the continuation of head winds, the boats did not reach Mackinac Island, their destination, until much later than usual, being approximately three days in transit. The predictions were well verified and much appreciated.

The commander of a group of six Army pursuit airplanes, desiring to make a test flight by night from Cheyenne, Wyo., to Chicago, wired the Chicago forecaster July 28 an inquiry as to good weather for night flying. Because of the large number of planes involved and the desirability of keeping in close formation on the journey, excellent weather was necessary, but local thunderstorms and more or less unsettled conditions were prevailing along the route. The commander at Cheyenne was so advised on the 28th and 29th. On the 30th, when conditions seemed to be improving from Cheyenne eastward almost to the Mississippi River, he was informed that comparatively clear conditions would prevail over that area, but that the weather would be mostly overcast in northern Illinois; and that the wind aloft, from 2,500 to 3,000 meters, would be favorable carrying winds. The trip was made that night, the 30th, and all planes landed safely at the flying field near Chicago, except one, which was forced down because of engine trouble.—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT

Moderate weather conditions prevailed over the west Gulf district during July, marked, however, by persistent drought over much of Texas and parts of Oklahoma and Louisiana. No storm warnings were ordered during the month, and no storm occurred on the west Gulf coast.—*I. M. Cline.*

DENVER FORECAST DISTRICT

The usual midsummer conditions prevailed, with frequent showers and thunderstorms in about all portions of the district except western Arizona. Occasional heavy downpours occurred during the last decade of the month in eastern Colorado and New Mexico. Temperatures averaged considerably above normal.

No special warnings, except flood warnings, were required.—*J. M. Sherier.*

SAN FRANCISCO FORECAST DISTRICT

July gave no exceptional weather conditions in this district other than a period of abnormally high temperatures in the interior during the middle of the month, attended by exceptionally high temperatures at many interior reporting stations, and resulting in the recording of higher readings than had been previously registered at a number of points in the Central Valley of California and at some of the stations in Nevada and southern Idaho. The oncoming of the heat wave was indicated by the regular forecasts and by special warnings disseminated when the fire hazard in the forested areas was expected to make fires easy to start and difficult to suppress. These advices now go by telegraph, telephone, or radio-telephone to those interested, and it is reported that they are most helpful.

Precipitation was light and local, as a rule, and attended by thunderstorms in nearly all instances. No cyclonic storms approached this district from the Pacific, although near the end of the month a disturbance of moderate intensity was off the Washington-Oregon coast and there were indications that it would move eastward and cross the coast line near Puget Sound. Instead, it moved northward and did not affect the weather conditions in any region except the Washington coast, where it produced light rains and strong southerly winds.—*E. H. Bowie.*

RIVERS AND FLOODS

By R. E. SPENCER

Low water.—Owing to the continued dryness of the summer, unusually low stages occurred in some of the rivers of the South, and the Mississippi, after a rise from the extreme low water of May and June, began dropping again about the middle of July and was still falling steadily at the end. Low-water records for this month were closely approached in the upper Tombigbee and Red Rivers; and in the Tennessee and lower Arkansas Rivers, where the condition was especially marked, stages fell lower at several stations than in any previous July of record. The following table gives comparative low stages for July on the two latter rivers:

Low water in July on Tennessee and lower Arkansas Rivers—1925 compared with previous record

Station	River	July, 1925, low-water record		Previous July low-water record	
		Stage	Date	Stage	Date
Knoxville, Tenn	Tennessee	−0.8	31	−0.5	1911
Loudon, Tenn	do	0.4	30–31	−0.5	1914
Rockwood, Tenn	do	2.5	31	4.2	1923
Chattanooga, Tenn. (pool stage, 6 feet).	do	6.9	25	0.8	1879
Hales Bar, Guild, Tenn., above dam (pool stage 37.5 feet).	do	39.0	25	6.9	1913
Hales Bar, Guild, Tenn., below dam	do	0.6	26	1.7	1914
Bridgeport, Ala. (pool stage 0.6 foot)	do	−0.2	26	0.1	{1899, 1914
Guntersville, Ala	do	0.6	28	4.2	1906
Decatur, Ala	do	0.2	31	0.2	1878
Upper Muscle Shoals, Ala	do	1.6	29–31	0.7	1899
Florence, Ala	do	−1.2	31	−0.7	1898
Riverton, Ala	do	6.8	31	7.4	1899
Savannah, Tenn	do	0.5	26	5.1	1922
Johnsonville, Tenn	do	0.7	8–9	0.5	{1879, 1914
Little Rock, Ark	Arkansas	−1.8	[1] 19	−1.6	1918
Pine Bluff, Ark	do	1.9	17–18	2.3	1918

[1] And subsequent dates.

Floods.—While heavy and widely scattered local rainfall continued, as in June, to cause floods of minor destructiveness in creeks and small streams, the only rise of consequence in an important river was that following the 21st of July in the Purgatoire of Colorado. This flood, resulting from heavy rain in the upper reaches of the river, did damage estimated at $43,400, of which $3,000 was in crops. No damage was reported from other floods in the Southwest.

The annual rise in the Columbia River finally subsided in early July. Owing to high temperature in April the rise began unusually early this year, but it was temporarily retarded before making important headway by a period of cold lasting about 10 days in the latter part of the month. During this period stages at several stations fell practically to the starting point; but beginning late in April and continuing for most of the next month the weather was again warm, with the result that the rise was steady and crests reached at all stations on the river in the last decade of May. The slight secondary rise which occurred in the latter part of June was without importance.

Columbia River water backing into the channel of the Willamette kept the latter above flood stage at Portland, Oreg., from April 20 to 24 and again from May 15 to July 6.

As to warnings for and damage by the flood, the official in charge of the Weather Bureau office at Portland, Oreg., reports as follows:

During the rise warnings were issued from day to day, giving advice as to stages that might be expected from three days to a week in advance, and so far as is known all movable property was saved in Portland and such movable property as was lost in other sections was mostly because of breaking of dikes, etc., and not because of lack of warnings. Losses reported to this office were as follows:

Tangible property	$18,525
Matured crops (mostly pasture)	9,700
Prospective crops	44,540
Movable property	17,595
Suspension of business, etc	6,050
Miscellaneous	225
Total	96,635

This office has statistics of property saved by the flood warnings amounting to $170,500, and it is known that the actual amount saved is much greater than this, for many patrons report that they saved entire stocks of goods without giving the value of the stocks.

On May 27, 1925, the new channel of the Arkansas River through the city of Pueblo, Colo., was opened. This channel, whose purpose is primarily to prevent future damaging overflow in the city, is roughly 3 miles long with a fall of 12 feet per mile, is adequately banked on the south by a natural 60 to 80 foot bluff and on the north by a 32-foot levee, and will accommodate at its narrowest point a discharge of 125,000 cubic feet of water per second—practically three times the capacity of the old channel.

For regulation of flow in the new channel and as a further measure for flood protection for the city, a barrier known as the Rock Creek Barrier is being constructed in the Arkansas channel, at right angles to its direction, 6½ miles above Pueblo. The combined length of this barrier and a 50-foot earth embankment of which it will be virtually a continuation, will be 3,000 feet. Openings will provide for a maximum flow through the completed structure of 100,000 cubic feet per second, as follows: 80,000 by the natural channel, 14,000 at the Denver & Rio Grande Western Railroad tracks, and 6,000 at the Bessemer ditch.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
Mississippi drainage					
	Feet			*Feet*	
Arkansas: Fort Lyon, Colo	6	21	[1] 24	7.3	23
Purgatoire:					
Trinidad, Colo	10	[1] 22	[1] 22	13.3	22
Higbee, Colo	4.5	[1] 21	[1] 23	5.6	23
Canadian: Logan, N. Mex	4	[1] 22	[1] 29	10.0	27
West Gulf drainage					
Pecos: Fort Sumner, N. Mex	7	[1] 23		8.0	23
Pacific drainage					
Colorado: Parker, Ariz	7	([2])	5	7.6	June 28–30
Columbia: Marcus, Wash	24	([2])	16	30.4	May 26
Willamette: Portland, Oreg	15	([2])	5	21.7	May 26

[1] Date uncertain. [2] Continued from last month.

MEAN LAKE LEVELS DURING JULY, 1925

By United States Lake Survey

[Detroit, Mich., Aug. 5, 1925]

The following data are reported in the "Notice to Mariners" of the above date:

Data	Lakes [1]			
	Superior	Michigan and Huron	Erie	Ontario
Mean level during July, 1925:	*Feet*	*Feet*	*Feet*	*Feet*
Above mean sea level at New York	601.39	578.52	571.11	245.21
Above or below—				
Mean stage of June, 1925	+0.17	+0.08	−0.08	−0.21
Mean stage of July, 1924	+0.07	−1.01	−1.33	−1.00
Average stage for July last 10 years	−1.03	−2.27	−1.67	−1.40
Highest recorded July stage	−2.43	−5.06	−3.30	−3.51
Lowest recorded July stage	+0.07	−1.01	−0.35	+0.62
Average departure (since 1860) of July level from June level	+0.21	+0.06	−0.03	−0.02

[1] Lake St. Clair's level: In July, 1925, 573.81 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, JULY-1925

By J. B. KINCER

General summary.—The continuation of showery conditions and prevailing warmth were favorable for the growth of crops during July in most Central and Northern States, although it was still too dry in some sections, particularly in the lower Great Plains. Substantial rains improved conditions materially in the western Lake region, and splendid growing weather prevailed in the Middle and North Atlantic States, but it was too warm during part of the month for small grain crops in portions of the Northwest.

In the South, crops made good growth wherever moisture was sufficient, but many sections continued too dry. Rainfall was especially insufficient over a considerable area in the Southeast, including western North Carolina, southwest Virginia, eastern Tennessee, and the northern portions of Georgia and South Carolina. It continued too dry also in parts of the Southwest, particularly in central and southern Texas, but good rains about the close of the month temporarily relieved the situation in most southwestern sections. Over the more western portions of the country conditions were generally favorable, except that during the latter part of the month the prevailing warm, dry weather unfavorably affected crops that were not irrigated. Farm work generally made satisfactory advance, though there was some interruption by rainfall in Central-Northern States.

Small grains.—The weather was favorable for threshing winter wheat and this work made good progress. Under the influence of favorable conditions spring wheat continued to make satisfactory advance during the first part of the month, but later it became too dry and warm in some sections and less favorable progress was reported. This was especially true in Minnesota and South Dakota, while some premature ripening was reported in Montana. The crop matured rapidly and harvest was well under way at the close of the month in nearly all sections of the belt, with threshing progressing in the south part. Warm weather in parts of the upper Mississippi Valley was somewhat unfavorable for oats, but with better soil moisture conditions the crop showed improvement in most of the northern part of the country, though there was much complaint of short straw. Rice improved in Arkansas and the early crop was being harvested in Louisiana, while generally favorable conditions for growth prevailed in California and Texas.

Corn.—The weather was generally favorable for the corn crop from the middle and upper Mississippi Valley eastward, except in some local areas where it was too dry. In the Plains States it was less favorable, as considerable areas were adversely affected by insufficient moisture. Conditions were especially favorable in the upper Ohio Valley districts and Middle Atlantic States where frequent showers and favorable warmth promoted rapid growth. At the close of the month there was need of moisture in parts of Iowa and Missouri, and deterioration was reported from many localities of the Plains States, especially in western Kansas and in Oklahoma.

Cotton.—In the central and eastern portions of the Cotton Belt rains were generally of a local character during the month, but were mostly sufficient to maintain cotton in a satisfactory state of growth. Some sections, however, were too dry and in these growth was slow. The month was too dry in parts of the western belt, particularly in central and southern Texas where the need of moisture was urgent, and cotton showed much deterioration, while in Oklahoma the latter part of the month was too dry. Rains at the close of the month temporarily relieved the droughty conditions over the southwestern portion of the belt. Cotton made fair progress in the western half and northeastern portion of Texas, and growth was fair to good in most other sections west of the Mississippi River. The weather was unusually favorable for maturing early cotton, and for picking and ginning and this work made rapid advance. In general, weevil and other insect activity was not serious in any section and only local damage was reported.

Miscellaneous crops.—With better moisture conditions, pastures showed improvement during the month in Central and Northern States, but it was too dry in most of the South, and rain was needed over much of the Great Plains. Rainfall during the latter part of the month was very beneficial over the southwestern grazing area and west of the Rocky Mountains stock interests in general were favorably affected by the weather. Potatoes did well in the Northeast and were favorably affected by the weather in most of the central valleys. Truck crops needed rain in most of the South.

CLIMATOLOGICAL TABLES [1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, July, 1925

Section	Temperature							Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	81.7	+1.6	Uniontown	106	26	Valley Head	54	30	4.83	−0.83	Spring Hill	12.72	Maple Grove	1.85
Alaska (June)	51.4	+0.4	Fortmann Hatchery	90	25	Pilot Station	24	12	2.81	+0.31	Ketchikan	9.17	Noorvik	0.19
Arizona	81.2	+1.2	Granite Reef Dam	121	16	Bright Angel Ranger Station.	37	8	2.05	−0.43	Rucker Canyon	7.91	2 stations	0.03
Arkansas	81.8	+1.9	Helena	109	16	Gravette	47	31	4.99	+1.07	Grannis	10.41	Corning	0.59
California	73.9	+1.4	Needles	125	16	Helm Creek	27	[2] 25	0.15	+0.08	Julian	2.45	96 stations	0.00
Colorado	67.7	+1.1	Lamar	110	18	2 stations	29	[2] 4	2.86	+0.48	Goodpasture	7.94	Rifle	0.02
Florida	81.4	+0.3	Garniers	100	13	do	62	[2] 21	7.26	+0.18	Plant City	15.22	Key West	2.42
Georgia	82.2	+2.1	Athens	108	3	Blue Ridge	46	30	3.49	−2.28	Waycross	8.12	Griffin	0.92
Hawaii	74.2	+0.3	Mahukona	94	20	Waimea	49	24	4.19	−2.37	Olokele (Mauka)	21.00	Lahaina	0.00
Idaho	70.9	+2.9	Glenns Ferry	115	16	2 stations	30	[2] 19	0.74	+0.01	Pocatello	3.33	Tripod Mountain	0.00
Illinois	75.8	−0.1	Decatur	105	2	Mount Carroll	44	29	2.96	−0.48	Freeport	6.42	Mount Vernon	0.71
Indiana	74.4	−0.9	Veedersburg	104	2	Rochester	41	23	4.27	+0.82	Anderson	10.82	Elliston	1.35
Iowa	74.1	+0.3	4 stations	105	1	Milford	40	22	2.66	−1.19	Dubuque	7.93	Sanborn	0.80
Kansas	79.8	+0.8	2 stations	112	18	Atwood	39	31	3.15	−0.20	Larned	8.75	Dresden	0.55
Kentucky	76.7	−0.2	do	105	2	3 stations	46	29	3.88	−0.29	Gest	9.21	Woodbury	0.68
Louisiana	83.0	+1.4	do	106	26	2 stations	62	[2] 20	5.44	−0.98	Homeplace	14.92	Ludington	0.40
Maryland-Delaware	74.8	−0.5	4 stations	100	[2] 7	do	36	1	5.06	+0.68	Millington, Md	8.73	Public Landing, Md.	1.88
Michigan	67.2	−1.4	Howell	101	6	do	30	30	3.27	+0.33	Edmore	8.00	St. James	0.87
Minnesota	67.5	−1.9	Canby	105	2	Pine River Dam	32	23	2.99	−0.43	Chatfield	7.85	Fosston	0.50
Mississippi	82.3	+1.6	University	106	15	University	57	30	4.87	−0.51	Biloxi	11.66	University	1.35
Missouri	77.9	+0.5	Clinton	106	8	Unionville	46	28	2.71	−1.34	Dean	8.60	Kirksville	0.57
Montana	68.3	+2.3	Biddle	110	14	Babb	28	21	1.31	−0.38	Wheaton	2.75	3 stations	T.
Nebraska	75.5	+0.9	Imperial	113	15	2 stations	34	31	2.16	−1.24	Greeley	4.85	Omaha	0.45
Nevada	74.6	+1.6	Logandale	117	14	5 stations	40	[2] 2	0.97	+0.56	Austin	2.45	Las Vegas	T.
New England	67.3	−1.0	Waterbury, Conn	98	12	Pittsburg, N. H	36	9	4.61	+0.83	Norwalk, Conn	11.81	Woodland, Me	1.44
New Jersey	72.0	−1.5	Indian Mills	99	7	Belleplain	39	1	7.37	+2.78	Belleplain	10.09	Runyon	4.03
New Mexico	72.7	+1.1	Orogrande	110	[2] 19	Red River	32	2	3.49	+0.78	Tatum	11.94	Bluewater	0.14
New York	67.6	−2.0	2 stations	101	7	Allegany State Park	33	1	4.81	+0.89	Port Jervis	9.66	Silver Bay	0.70
North Carolina	78.0	+2.1	4 stations	102	[2] 6	Mount Mitchell	42	18	3.00	−3.18	Southport	10.30	Caroleen	0.13
North Dakota	66.7	−0.8	2 stations	106	[2] 12	Carson	29	[2] 30	1.34	−1.27	Mott	3.07	3 stations	0.33
Ohio	72.0	−1.7	Hamilton	103	2	2 stations	39	1	4.69	+0.89	Cincinnati, Gov't Bldg.	10.53	New Bremen	1.80
Oklahoma	83.7	+2.8	Mangum	113	[2] 14	Watts	49	31	3.95	+1.13	Newkirk	10.70	Kingfisher	1.05
Oregon	69.9	+2.9	Echo	111	31	Fremont	30	7	0.17	−0.34	Paisley	2.44	22 stations	0.00
Pennsylvania	70.5	−1.8	Phoenixville	101	7	West Bingham	32	1	5.57	+1.55	Colebrook	14.95	Bradys Bend	1.54
Porto Rico	78.4	−0.4	2 stations	95	[2] 10	Toro Negro	57	10	6.38	−0.13	Maricao	18.75	Potala	1.14
South Carolina	81.5	+1.7	Calhoun Falls	106	3	2 stations	56	[2] 18	3.19	−2.70	Pinopolis	13.95	Little Mountain	0.30
South Dakota	71.5	−0.4	Pukwana	108	13	Camp Crook	30	31	1.74	−0.99	Oelrichs	6.69	McIntosh	0.00
Tennessee	79.1	+1.8	2 stations	106	[2] 2	Crossville	44	30	3.34	−1.21	Moscow	8.09	Rugby	0.90
Texas	85.6	+2.7	3 stations	113	[2] 10	Clint	52	31	1.92	−0.69	Angleton	6.52	5 stations	0.00
Utah	72.8	+1.6	St. George	115	16	Woodruff	33	26	1.29	+0.32	Trout Creek Ranger Station.	3.65	Lucin	T.
Virginia	76.4	+0.7	Troy	102	[2] 7	Burkes Garden	38	19	3.00	−1.53	Cape Henry	7.10	Chatham	0.64
Washington	68.3	+2.7	Wahluke	110	31	2 stations	35	19	0.15	−0.52	Forks	2.58	35 stations	0.00
West Virginia	72.2	−0.9	Point Pleasant	102	6	Cheat Bridge	31	29	5.05	+0.21	Bruceton Mills	7.84	Union	1.08
Wisconsin	68.2	−1.1	Danbury	99	12	Long Lake	33	[2] 30	4.28	+0.57	Grantsburg	8.78	Port Washington	1.66
Wyoming	66.9	+1.4	Basin	108	14	Snake River	24	26	1.63	+0.16	Archer	3.91	Lovell	0.14

[1] For description of tables and charts, see Review, January, 1925, p. 42.

[2] Other dates also.

TABLE I.—*Climatological data for Weather Bureau stations, July, 1925*

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							**67.8**	**−1.1**										**78**	**4.00**	**+0.4**										**5.0**		
Eastport	76	67	85	29.82	29.90	−.03	58.3	−2.1	82	11	66	46	6	50	34	56	55	91	2.69	−0.7	14	4,615	s.	27	nw.	1	4	11	16	6.9	0.0	0.0
Greenville, Me	1,070	6		28.76	29.91		62.6		81	6	72	45	4	53	34				5.80		19		se.				9	11	11		0.0	0.0
Portland, Me	103	82	117	29.81	29.93	−.02	67.0	−1.1	86	11	75	51	1	59	24	61	57	75	2.62	−0.6	13	5,954	s.	36	s.	16	10	11	10	5.2	0.0	0.0
Concord	288	70	79	29.60	29.91	−.05	68.4	−0.1	94	7	80	46	31	57	36				3.49	−0.3	10	1,905	w.	5	nw.	1	20	7	4	3.5	0.0	0.0
Burlington	404	11	48	29.47	29.89	−.05	66.0	−4.3	84	10	75	48	31	57	33				6.50	+2.7	13	6,644	s.	40	s.	16	4	13	14	6.6	0.0	0.0
Northfield	876	12	60	28.99	29.92	−.02	63.2	−2.7	84	6	75	41	31	52	36	60	57	80	5.24	+1.5	14	4,617	s.	30	sw.	16	2	16	13	6.7	0.0	0.0
Boston	125	115	188	29.79	29.92	−.04	72.4	+0.7	95	7	80	54	1	64	28	64	59	68	3.54	+0.2	10	6,573	sw.	30	nw.	7	11	14	6	5.1	0.0	0.0
Nantucket	12	14	90	29.92	29.94	−.04	67.8	0.0	81	11	75	54	3	61	18	64	62	86	2.29	−0.4	7	9,245	sw.	35	s.	22	13	12	6	4.9	0.0	0.0
Block Island	26	11	46	29.91	29.94	−.03	69.2	+0.8	80	12	74	57	4	64	15	64	62	84	1.87	−1.4	8	9,030	sw.	40	w.	7	19	6	6	3.7	0.0	0.0
Providence	160	215	251	29.76	29.93	−.04	71.3	−2.1	92	7	80	51	1	62	27	64	59	69	3.56	0.0	11	6,446	w.	42	nw.	7	14	10	7	4.7	0.0	0.0
Hartford	159	122	140	29.76	29.93	−.04	71.3	−0.3	94	7	80	52	1	62	26				5.68	+1.6	14		s.				18	5	8	3.9	0.0	0.0
New Haven	106	74	153	29.82	29.93	−.04	71.1	−0.7	92	12	79	55	1	63	24	65	62	73	6.49	+1.7	15	5,699	s.	30	s.	22	13	10	8	4.3	0.0	0.0
Middle Atlantic States							**74.4**	**−0.3**										**74**	**5.44**	**+1.1**										**5.2**		
Albany	97	102	115	29.82	29.91	−.05	70.6	−2.0	95	7	80	52	30	61	29	64	60	72	3.08	−0.8	11	5,456	s.	31	s.	4	12	13	6	4.7	0.0	0.0
Binghamton	871	10	84	29.01	29.92	−.05	68.4	−1.6	91	7	79	49	18	58	33				4.66	+1.1	12	3,527	w.	20	sw.	16	8	11	12	6.0	0.0	0.0
New York	314	414	454	29.61	29.94	−.04	72.5	−1.3	91	12	80	56	1	22	65	65	61	72	6.05	+1.5	13	10,286	s.	60	nw.	28	5	13	13	6.4	0.0	0.0
Harrisburg	374	94	104	29.56	29.95	−.03	73.6	−1.2	94	7	82	54	1	65	27	66	61	69	7.26	+3.4	14	4,004	nw.	33	nw.	7	6	11	14	6.2	0.0	0.0
Philadelphia	114	123	190	29.82	29.94	−.04	76.2	0.0	96	12	85	60	1	68	24	69	65	73	4.99	+0.7	13	5,684	nw.	41	ne.	12	8	15	8	5.5	0.0	0.0
Reading	325	81	98	29.60	29.94		73.4		97	7	83	54	1	64	27	66	63	72	11.66	+7.4	16	3,918	se.	25	sw.	16	10	12	9	5.6	0.0	0.0
Scranton	805	111	119	29.10	29.95	−.03	69.4	−2.3	90	7	79	49	18	60	31	66	65	88	6.80	+3.0	13	4,190	s.	24	nw.	16	7	10	14	6.3	0.0	0.0
Atlantic City	52	37	172	29.89	29.94	−.04	72.5	+0.4	92	12	79	56	1	66	19	68	65	79	7.06	+3.3	12	10,571	s.	55	se.	31	15	8	8	4.4	0.0	0.0
Cape May	17	13	49	29.96	29.98	.00	74.4	+1.0	91	10	82	56	1	67	22	68	66	80	4.30	+0.5	13	4,476	s.	16	se.	31	12	9	10	4.8	0.0	0.0
Sandy Hook	22	10	55	29.91	29.93		73.0		90	12	80	60	1	66	20	66	64	77	4.78		15	8,727	s.	44	se.	31	10	12	9	4.8	0.0	0.0
Trenton	190	159	183	29.74	29.94		73.3		92	6	83	55	1	64	25	66	63	72	5.15	+0.4	15	5,906	nw.	31	ne.	8	9	10	12	5.7	0.0	0.0
Baltimore	123	100	113	29.81	29.93	−.05	77.2	0.0	97	7	86	59	1	68	25	69	65	70	5.57	+0.8	15	3,880	s.	33	sw.	7	10	13	8	5.5	0.0	0.0
Washington	112	62	85	29.82	29.94	−.06	76.8	0.0	98	7	86	54	1	67	28	69	65	70	3.82	−0.8	14	3,988	nw.	25	nw.	10	7	16	8	5.5	0.0	0.0
Cape Henry	18	8	54	29.92	29.94		78.3		96	8	86	63	30	71	25	72	69	76	7.10	+1.2	6	7,805	sw.	46	nw.	26	14	14	3	3.8	0.0	0.0
Lynchburg	681	153	188	29.23	29.96	−.05	77.8	+0.7	97	2	89	55	19	67	31	68	64	68	3.56	−0.5	7	4,723	w.	52	n.	2	11	17	3	4.6	0.0	0.0
Norfolk	91	170	205	29.87	29.96	−.04	79.6	+0.9	94	11	88	65	30	71	25	71	68	73	5.52	−0.3	9	8,468	s.	58	w.	31	10	18	3	4.6	0.0	0.0
Richmond	144	11	52	29.80	29.95	−.06	79.6	+1.1	98	10	91	58	19	68	25	70	66	68	2.32	−2.1	7	5,446	sw.	40	sw.	8	10	19	2	4.4	0.0	0.0
Wytheville	2,304	49	55	27.67	29.95	−.06	72.2	−0.4	90	3	83	48	19	61	28	64	61	72	3.64	−0.8	8	3,837	w.	26	n.	13	7	18	6	5.1	0.0	0.0
South Atlantic States							**81.0**	**+1.8**										**75**	**2.84**	**−3.2**										**5.4**		
Asheville	2,255	70	84	27.70	29.97	−.05	74.5	+2.8	92	3	85	52	19	64	27	65	62	71	0.77	−4.0	10	4,887	nw.	27	n.	3	6	22	3	4.9	0.0	0.0
Charlotte	779	55	62	29.16	29.97	−.05	81.4	+3.0	99	13	92	63	19	71	29	70	65	64	0.62	−4.9	8	2,886	sw.	21	w.	31	9	14	8	5.4	0.0	0.0
Hatteras	11	11	50	29.96	29.97	−.04	78.6	+0.4	89	27	84	67	30	74	16	74	72	82	2.76	−3.4	8	9,447	sw.	40	nw.	13	13	12	6	4.6	0.0	0.0
Raleigh	376	103	110	29.58	29.96	−.06	80.3	+1.5	96	12	91	62	30	70	27	71	67	70	1.98	−4.1	7	5,660	sw.	39	w.	11	9	13	9	5.4	0.0	0.0
Wilmington	78	81	91	29.91	29.99	−.02	80.7	+1.6	97	28	88	67	18	73	25	74	72	81	4.25	−2.7	13	5,334	sw.	31	n.	13	11	16	4	4.5	0.0	0.0
Charleston	48	11	92	29.94	29.99	−.04	82.8	+1.4	98	27	89	72	31	77	24	77	76	81	2.38	−4.9	10	7,477	sw.	29	nw.	31	3	17	11	6.2	0.0	0.0
Columbia, S. C	351	41	57	29.61	29.98	−.04	82.8	+1.9	99	3	93	65	19	73	25	73	70	73	3.50	−2.6	10	4,488	s.	25	sw.	31	3	24	4	5.5	0.0	0.0
Due West	711	10	55	29.25	30.00		81.8		99	3	93	64	19	71	29				1.79		11	5,214	sw.	46	sw.	6	5	25	1	5.4	0.0	0.0
Greenville, S. C	1,039	113	122	28.90	29.96		80.6	+3.7	98	3	90	66	18	71	26	70	65	65	2.38		8	4,759	e.	36	se.	7	6	21	4	4.9	0.0	0.0
Augusta	182	62	77	29.78	29.97	−.05	83.6	+2.3	101	3	94	68	19	74	27	74	71	72	2.93	−2.4	7	3,832	s.	33	s.	13	4	19	8	6.0	0.0	0.0
Savannah	65	150	194	29.92	29.99	−.04	83.0	+1.5	98	3	92	69	14	74	28	75	73	81	3.96	−2.2	13	7,678	sw.	50	ne.	13	6	21	4	5.1	0.0	0.0
Jacksonville	43	209	245	29.97	30.02	−.01	82.2	+0.1	95	5	90	71	28	74	23	75	73	81	5.22	−1.0	16	8,485	sw.	48	n.	28	5	13	13	6.3	0.0	0.0
Florida Peninsula							**82.6**	**+0.4**										**75**	**6.10**	**0.0**										**6.0**		
Key West	22	10	64	30.01	30.03	.00	83.7	+0.2	92	27	89	71	3	78	18	76	74	74	2.42	−1.2	10	5,880	se.	25	sw.	29	11	14	6	5.0	0.0	0.0
Miami	25	71	79	30.02	30.05		82.5	+0.6	92	28	88	73	8	78	16	75	73	73	2.56	−3.6	12	5,056	e.	24	w.	31	5	20	6	5.4	0.0	0.0
Tampa	35	79	87	30.00	30.03	−.01	81.6	+0.4	93	24	89	68	6	75	24	75	72	78	13.32	+4.9	18	3,747	e.	36	e.	6	1	15	15	7.4	0.0	0.0
Titusville	44	5		29.98	30.04		80.5		96	27	88	68	21	72	22				8.90		14		sw.				10	3	18	6.1	0.0	0.0
East Gulf States							**81.6**	**+0.9**										**75**	**6.25**	**+0.9**										**5.8**		
Atlanta	1,174	190	216	28.79	30.00	−.02	80.8	+2.7	101	3	90	67	18	72	25	70	65	65	2.35	−2.4	7	6,913	nw.	40	nw.	22	10	8	13	5.9	0.0	0.0
Macon	370	78	87	29.60	29.98	−.04	82.7	+1.5	101	3	93	66	30	72	29	72	68	67	1.63	−3.0	8	3,827	sw.	28	nw.	13	8	14	9	5.5	0.0	0.0
Thomasville	273	49	58	29.72	30.01	−.02	81.6	−0.2	96	13	92	67	3	72	27	74	71	79	7.06	+1.7	15	2,975	sw.	25	ne.	5	3	16	12	6.5	0.0	0.0
Apalachicola	36	42	49	29.98	30.02		81.8		93	29	88	72	16	75	18	76	74	79	7.06		11	4,606	w.	25	se.	14	15	12	4	4.3	0.0	0.0
Pensacola	56	149	185	29.95	30.02	+.01	81.0	0.0	95	13	87	69	17	75	19	76	74	82	8.14	+0.9	11	7,429	w.	58	w.	29	4	15	12	6.4	0.0	0.0
Anniston	741	9	57	29.25	30.02	.00	80.1	+2.2	101	3	92	58	30	68	32				8.30	+3.6	14	2,440	s.	24	nw.	12	12	14	5	4.4	0.0	0.0
Birmingham	700	11	48	29.27	30.02	+.01	81.4	+1.2	99	3	92	64	30	71	31	70	67	70	5.52	+0.8	16	3,619	sw.	38	se.	25	10	12	9	5.0	0.0	0.0
Mobile	57	125	161	29.96	30.02	+.01	81.6	+0.2	98	13	90	68	19	74	28	75	73	80	9.35	+2.3	15	5,396	w.	62	nw.	31	1	20	10	6.5	0.0	0.0
Montgomery	223	100	112	29.76	30.00	−.02	82.4	+0.7	99	3	92	67	3	72	32	73	70	75	5.47	+0.8	14	4,071	sw.	36	e.	3	6	16	9	5.8	0.0	0.0
Corinth	469	6					82.2		102	2	94	62	30	71	30				3.24		5		s.				3	27	1		0.0	0.0
Meridian	375	85	93	29.61	29.99	−.03	80.9	+0.5	98	26	90	67	18	72	25	73	71	77	6.92	+2.4	17	3,252	sw.	36	sw.	15	5	19	7	5.9	0.0	0.0
Vicksburg	247	65	73	29.74	30.02	+.02	82.1	+0.8	99	26	90	69	18	74	25	73	70	73	4.11	−0.3	10	3,980	sw.	28	ne.	26	6	7	18	6.6	0.0	0.0
New Orleans	53	76	84	29.97	30.02	+.02	82.6	+0.2	97	13	90	69	14	75	20	75	73	78	9.90	+3.4	17	3,684	sw.	25	ne.	29	5	14	12	6.5	0.0	0.0
West Gulf States							**84.1**	**+1.6**										**70**	**2.20**	**−0.9**										**4.3**		
Shreveport	249	77	93	29.72	29.98	.00	85.4	+2.2	103	26	95	64	31	76	28	73	69	66	1.71	−2.0	10	4,750	s.	20	nw.	18	10	18	3	4.6	0.0	0.0
Bentonville	1,303	11	44				77.8	−0.7	97	1	88	56	17	68	33				2.40		13	2,961	s.	18	se.	20	17	6	8		0.0	0.0
Fort Smith	457	79	94	29.48	29.95	−.02	82.0	+0.5	101	25	91	64	31	73	29	73	70	74	5.39	+1.6	12	4,713	e.	34	se.	2	6	13	12	6.3	0.0	0.0
Little Rock	357	136	144	29.60	29.97	−.02	81.5	+0.6	99	1	90	65	31	73	28	72	69	71	5.46	+1.5	14	5,186	s.	44	n.	14	6	16	9	6.2	0.0	0.0
Brownsville	57	53	61	29.89	29.95		84.0	+0.4	95	14	92	72	1	76	21	75	73	77	0.04		1	6,839	s.	26	s.	20	20	10	1	2.5	0.0	0.0
Corpus Christi	20	11	73	29.95	29.98	+.02	84.0	+1.3	99	15	90	74	14	78	22	77	74	79	0.05	−1.6	1	11,738	se.	37	se.	15	21	8	2	2.8	0.0	0.0
Dallas	512	109	117	29.42	29.95		87.2		105	14	97	69	31	77	29				1.78		6	5,835	s.	33	ne.	14	15	12	4	4.1	0.0	0.0
Fort Worth	670	106	114	29.21	29.91	−.05	88.2	+4.6	107	18	98	66	31	78	30	72	64	52	0.98	−1.6	4	7,243	s.	40	ne.	14	9	19	3	4.8	0.0	0.0
Galveston	54	106	114	29.96	30.02	+.04	82.9	−0.5	91	14	87	69	11	79	16	76	74	79	3.90	−0.1	8	7,963	s.	25	sw.	11	21	9	1	3.1	0.0	0.0
Groesbeck	461	11	56	29.48	29.95		86.4		105	14	98	66	1	75	26				1.78		4	7,861	s.	52	se.	1	11	17	3	4.3	0.0	0.0
Houston	138	111	121	29.86	30.00		84.6	+0.9	100	14	94	69	11	75	25				2.49		7	4,950	s.	22	se.	2	18	11	2	3.5	0.0	0.0
Palestine	510	64	72	29.44	29.96	−.01	85.5	+3.3	104	14	96	66	31	75	29	72	66	61	0.59	−2.4	5	5,188	sw.	34	nw.	14	4	25	2	5.6	0.0	0.0
Port Arthur	34	58	66	29.96	30.00		84.1		97	31	91	69	1	77	23	76	73	76	3.32		10	7,045	s.	29	n.	31	11	15	5	4.6	0.0	0.0
San Antonio	693	119	132	29.24	29.95	.00	86.0	+2.2	102	15	97	70	15	75	32	72	67	62	1.24	−1.0	5	6,026	s.	52	nw.	15	17	12	2	3.0	0.0	0.0
Taylor	583	55	63	29.40	30.01	+.05	87.0	+4.3	106	14	98	69	1	76	28				0.48	−2.1	2	8,019	s.	31	se.	2	11	18	2	4.3	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, July, 1925*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
Ohio Valley and Tennessee							76.3	−0.2										67	3.93	−0.1										5.3		
Chattanooga	762	189	213	29.18	29.96	−.06	80.7	+2.3	100	3	91	63	19	70	29	68	63	61	3.68	−0.2	11	5,094	w.	37	nw.	3	10	18	3	4.8	0.0	0.0
Knoxville	996	102	111	28.94	29.96	−.06	80.0	+2.9	99	3	91	60	30	69	32	69	64	63	1.46	−2.8	11	4,530	sw.	28	ne.	3	9	20	2	4.5	0.0	0.0
Memphis	399	76	97	29.55	29.97	−.03	82.2	+1.5	99	16	90	64	31	74	25	71	67	64	5.92	+2.4	8	4,216	sw.	40	n.	26	12	11	8	4.7	0.0	0.0
Nashville	546	168	191	29.41	29.99	−.02	80.4	+1.3	100	3	90	58	29	70	32	69	64	63	1.74	−2.6	8	5,546	w.	40	ne.	13	12	18	1	4.4	0.0	0.0
Lexington	989	193	230	28.94	29.98	−.03	75.0	−0.9	97	3	84	58	31	66	31				3.63	−0.8	12	7,961	sw.	52	nw.	3	13	13	5	4.5	0.0	0.0
Louisville	525	188	234	29.41	29.98	−.02	77.6	−1.0	100	2	87	58	29	68	27	68	63	66	2.63	−1.1	11	6,638	s.	54	nw.	25	9	17	5	4.6	0.0	0.0
Evansville	431	139	175	29.51	29.98	−.02	79.6	+0.9	98	3	89	60	31	70	27	69	64	64	1.92	−1.9	7	6,155	sw.	46	w.	25	6	24	1	5.4	0.0	0.0
Indianapolis	822	194	230	29.09	29.96	−.03	74.7	−1.0	98	2	84	55	28	66	30	66	61	67	4.67	+0.5	11	6,782	sw.	82	ne.	12	7	20	4	5.1	0.0	0.0
Royal Center	736	11	55	29.17	29.95		71.4		95	3	82	47	23	60	35				5.30		9	5,617	s.	64	sw.	3	3	13	15	6.4	0.0	0.0
Terre Haute	575	96	129	29.35	29.95		76.4		101	2	86	56	18	67	30	67	63	67	1.53		8	5,730	s.	37	w.	25	3	25	3	5.0	0.0	0.0
Cincinnati	627	11	51	29.30	29.96	−.04	74.6	−0.5	98	2	85	54	1	64	31		63	69	9.13	+5.6	16	4,274	sw.	32	sw.	2	11	11	9	4.8	0.0	0.0
Columbus	822	179	222	29.11	29.97	−.03	73.0	−1.9	93	9	82	54	1	64	29	64	60	69	3.27	−0.4	11	6,162	nw.	49	nw.	4	5	15	11	5.9	0.0	0.0
Dayton	899	137	173	29.01	29.94		73.9	−1.5	95	2	84	54	1	64	29	65	60	67	2.91	−0.4	11	5,728	sw.	36	nw.	4	8	18	5	5.0	0.0	0.0
Elkins	1,947	59	67	27.99	29.98	−.03	69.2	−1.1	90	6	80	44	29	58	36	63	61	82	4.81	+0.2	17	2,691	w.	34	w.	7	1	21	9	6.5	0.0	0.0
Parkersburg	638	77	84	29.34	29.99	−.02	74.5	−0.9	96	6	84	50	29	65	32	66	62	71	5.44	+0.8	12	2,904	sw.	30	nw.	4	8	11	12	6.0	0.0	0.0
Pittsburgh	842	353	410	29.07	29.95	−.05	72.4	−2.2	92	6	81	51	1	63	29	64	60	69	3.81	−0.6	11	6,326	sw.	44	nw.	16	2	15	14	7.0	0.0	0.0
Lower Lake Region							69.5	−2.1										70	4.02	+0.6										5.4		
Buffalo	767	247	280	29.11	29.92	−.05	67.6	−2.2	83	6	74	51	29	61	22	63	60	76	3.28	−0.1	10	9,882	sw.	56	w.	16	8	12	11	5.6	0.0	0.0
Canton	448	10	61	29.41	29.87		65.5	−5.5	87	6	76	45	3	55	37				5.46	+2.2	13	5,740	sw	39	sw.	16	16	7	8	4.4	0.0	0.0
Oswego	335	76	91		29.90	−.06	66.6	−3.8	89	6	74	50	1	59	31			75	2.15	−1.1	15		s.	28	nw.	28	8	13	10		0.0	0.0
Rochester	523	86	102	29.37	29.92	−.05	68.8	−1.9	91	6	78	49	1	60	30	61	57	66	3.44	+0.4	13	5,193	w.	22	nw.	28	9	12	10	5.5	0.0	0.0
Syracuse	597	97	113	29.30	29.94	−.03	67.8	−3.0	89	6	76	52	31	60	30				5.05	+1.4	14	6,863	s.	35	nw.	16	8	9	14	6.1	0.0	0.0
Erie	714	130	166	29.17	29.92	−.06	70.3	−0.7	90	11	78	50	1	63	28	65	62	74	2.70	−0.5	12	8,089	w.	29	sw.	2	5	21	5	5.3	0.0	0.0
Cleveland	762	190	201	29.13	29.94	−.05	70.8	−0.6	88	6	78	49	1	64	30	64	59	68	4.52	+1.0	13	8,072	s.	35	n.	17	3	19	9	6.2	0.0	0.0
Sandusky	629	62	70	29.28	29.95	−.04	71.6	−1.8	92	9	80	51	1	64	31				3.63	−0.2	15	5,323	sw.	29	nw.	16	3	19	9	6.1	0.0	0.0
Toledo	628	208	243	29.28	29.95	−.04	72.1	−1.1	93	6	81	53	23	63	28	64	59	66	3.03	−0.2	10	8,147	sw.	32	sw.	20	14	13	4	4.4	0.0	0.0
Fort Wayne	856	113	124	29.04	29.95		72.3	−1.2	93	11	82	53	23	62	29	64	60	69	3.53		13	5,474	sw.	42	nw.	12	12	12	7	5.4	0.0	0.0
Detroit	730	218	258	29.17	29.94	−.04	71.0	−1.1	92	6	80	53	31	62	26	62	56	64	6.94	+3.5	8	6,476	nw.	28	sw.	6	9	16	6	5.2	0.0	0.0
Upper Lake Region							66.9	−1.3										72	3.01	−0.1										5.1		
Alpena	609	13	92	29.28	29.94	−.03	63.8	−2.1	90	6	73	43	30	54	31	59	55	75	2.14	−0.9	10	7,483	nw.	38	nw.	16	11	12	8	5.4	0.0	0.0
Escanaba	612	54	60	29.28	29.93	−.04	64.4	−1.6	86	10	73	44	30	56	28	59	56	77	3.02	−0.3	13	6,486	s.	34	nw.	15	10	12	9	4.9	0.0	0.0
Grand Haven	632	54	89	29.26	29.92	−.06	67.4	−1.3	90	12	75	50	18	60	26	62	58	73	5.83	+3.2	11	6,413	w.	31	ne.	15	12	13	6	5.0	0.0	0.0
Grand Rapids	707	70	87	29.19	29.94	−.04	70.9	−1.4	95	3	81	49	28	61	29	62	56	62	4.58	+2.0	13	3,696	nw.	28	nw.	6	8	12	11	5.9	0.0	0.0
Houghton	668	62	99	29.20	29.92	−.04	63.9	−1.6	93	15	73	43	30	54	30				0.94	−2.2	11	6,547	w.	42	sw.	15	13	10	8	4.7	0.0	0.0
Lansing	878	11	62	29.01	29.93		69.4	−1.5	96	6	82	47	29	57	34	63	59	73	3.41	+0.2	17	3,271	nw.	18	nw.	16	10	14	7	5.0	0.0	0.0
Ludington	637	60	66	29.25	29.94		65.1		85	12	72	48	30	58	24	61	58	77	2.25		11	5,854	s.	28	n.	16	15	10	6	4.0	0.0	0.0
Marquette	734	77	111	29.16	29.95	−.01	63.3	−1.6	94	15	72	43	29	54	34	57	53	70	1.66	−1.4	12	5,994	n.	35	sw.	13	10	10	11	5.5	0.0	0.0
Port Huron	638	70	120	29.25	29.93	−.05	67.4	−1.4	91	6	77	47	1	58	29	61	57	70	4.27	+1.5	10	7,158	ne.	34	nw.	7	10	17	4	4.3	0.0	0.0
Saginaw	641	69	77	29.25	29.94		68.6	−2.5	94	6	80	47	28	57	32	62	58	70	2.92	−0.8	12		nw.				6	15	10	6.3	0.0	0.0
Sault Ste. Marie	614	11	52	29.24	29.93	−.04	61.0	−2.8	86	15	70	45	24	52	28	56	54	80	1.24	−1.5	11	5,207	nw.	30	nw.	15	5	17	9	5.6	0.0	0.0
Chicago	823	140	310	29.08	29.94	−.04	73.0	−0.9	98	3	80	57	31	66	31	64	58	63	2.47	−1.2	11	6,640	n.	33	nw.	6	7	19	5	5.3	0.0	0.0
Green Bay	617	109	141	29.26	29.91	−.06	68.5	−1.5	92	11	78	50	31	59	28	62	58	72	3.04	−0.5	16	6,537	s.	34	nw.	21	12	13	6	4.9	0.0	0.0
Milwaukee	681	125	139	29.21	29.94	−.03	70.2	+0.1	94	3	78	54	28	62	33	62	58	67	3.39	+0.4	15	5,930	n.	30	nw.	12	10	9	12	5.5	0.0	0.0
Duluth	1,133	5	47	28.74	29.94	−.01	65.4	+1.5	90	14	76	42	29	55	30	61	59	82	3.17	−0.5	14	8,134	nw.	38	nw.	15	11	16	4	4.5	0.0	0.0
North Dakota							67.4	−1.3										65	1.84	−1.1										3.7		
Moorhead	940	50	58	28.96	29.96	+.02	68.2	+0.1	98	11	80	45	22	56	37	62	57	69	4.35	+0.6	7	4,819	nw.	25	nw.	15	22	6	3	3.0	0.0	0.0
Bismarck	1,674	8	57	28.27	30.03	+.10	68.6	−1.2	100	12	81	44	30	56	38	58	52	61	0.42	−1.7	6	5,559	n.	38	nw.	7	19	9	3	3.1	0.0	0.0
Devils Lake	1,478	11	44	28.43	29.98	+.05	65.8	−2.3	97	14	78	40	22	53	37	59	54	69	1.40	−2.4	8	6,098	nw.	34	w.	19	17	7	7	3.9	0.0	0.0
Ellendale	1,457	10	56	28.44	29.99		67.0		94	12	79	42	22	55	36				1.22		8	8,245	nw.	50	n.	13	10	15	6	5.1	0.0	0.0
Grand Forks	835	12	89				65.8		92	13	77	42	27	54	31	61			1.32		11		nw.	37	nw.	15	18	10	3		0.0	0.0
Williston	1,878	41	48	28.04	29.98	+.06	67.2	−1.7	101	14	81	41	31	54	43	57	50	60	1.18	−0.8	8	5,389	ne.	43	nw.	12	16	14	1	3.2	0.0	0.0
Upper Mississippi Valley							74.4	−0.6										69	3.72	+0.1										4.8		
Minneapolis	918	102	208	28.97	29.93		70.8	−1.5	97	11	80	52	28	61	26				4.03	+0.2	9	7,309	nw.	44	nw.	8	10	9	12	5.3	0.0	0.0
St. Paul	837	236	261	29.05	29.94	−.01	70.0	−2.1	95	11	80	51	22	60	27				4.28	+0.9	9	7,746	nw.	56	nw.	8	9	15	7	5.0	0.0	0.0
La Crosse	714	11	48	29.18	29.93	−.03	70.6	−2.2	95	11	80	50	28	61	28				5.83	+1.8	14	2,755	s.	27	nw.	13	10	7	14	5.8	0.0	0.0
Madison	974	70	78	28.92	29.94	−.03	70.7	−1.4	91	3	79	52	28	62	31	64	61	74	3.30	−0.7	9	5,031	nw.	22	nw.	3	9	15	7	5.1	0.0	0.0
Wausau	1,247	4		28.63	29.95		67.6		91	11	78	46	31	58	31				4.92		17		n.				10	8	13	5.7	0.0	0.0
Charles City	1,015	10	49	28.90	29.95	−.01	71.1	−1.2	95	1	82	47	28	60	32	65	61	73	2.99	−0.6	12	3,691	nw.	20	nw.	13	15	13	3	3.7	0.0	0.0
Davenport	606	71	79	29.29	29.94	−.03	75.2	−0.1	99	11	86	52	28	64	32	66	62	67	3.34	−0.2	11	4,190	nw.	28	nw.	12	11	16	4	4.7	0.0	0.0
Des Moines	861	84	97	29.06	29.94	−.02	76.3	+0.9	104	1	88	52	31	65	39	66	61	66	2.21	−1.6	3	4,521	n.	26	ne.	3	15	8	8	4.6	0.0	0.0
Dubuque	700	81	96	29.19	29.92	−.05	72.5	−1.6	96	3	82	52	28	62	36	65	62	71	7.93	+3.6	15	3,848	nw.	32	sw.	3	6	14	11	5.9	0.0	0.0
Keokuk	614	64	78	29.29	29.95	−.03	76.6	−0.3	100	2	86	51	31	67	33	69	65	68	3.90	−0.1	10	4,334	nw.	35	n.	6	12	13	6	4.5	0.0	0.0
Cairo	358	87	93	29.58	29.95	−.05	80.0	+0.4	98	2	89	60	31	71	28	70	66	68	2.08	−1.4	8	4,420	s.	26	ne.	13	7	15	9	5.5	0.0	0.0
Peoria	609	11	45	29.31	29.97	−.01	75.0	−0.4	100	2	86	52	23	64	33	67	64	71	3.93	+1.0	13	3,455	nw.	20	sw.	6	17	9	5	3.3	0.0	0.0
Springfield, Ill.	636	10	91	29.27	29.94	−.04	77.0	+0.5	102	2	87	56	31	67	32	68	65	69	3.51	+0.6	12	4,929	w.	27	nw.	6	11	16	4	4.4	0.0	0.0
Hannibal	534	74	109	29.39	29.95	−.03	76.6	−0.2	98	2	86	52	31	67	28				2.96	−0.8	9	4,969	sw.	34	n.	6	15	8	8	4.2	0.0	0.0
St. Louis	568	265	303	29.36	29.96	−.03	79.0	+0.4	97	2	87	58	31	71	27	69	65	66	1.78	−1.6	7	7,482	sw.	52	w.	25	12	14	5	4.4	0.0	0.0
Missouri Valley							76.4	+0.5										62	2.28	−1.6										4.1		
Columbia, Mo.	784	11	84	29.14	29.95	−.03	77.0	+0.1	96	6	87	52	31	67	30				2.01	−1.6	7	4,217	sw.	25	nw.	2	11	15	5	4.7	0.0	0.0
Kansas City	963	161	181	28.95	29.95	−.02	78.3	+0.2	100	8	88	54	31	69	25	68	64	65	3.00	−1.8	8	6,135	s.	38	nw.	14	14	14	3	4.0	0.0	0.0
St. Joseph	967	11	49	28.94	29.94		78.2		100	1	88	54	31	68	28	68	64	66	3.30		9	4,531	sw.	41	nw.	14	21	8	2	2.8	0.0	0.0
Springfield, Mo.	1,324	98	104	28.61	29.98	.00	76.6	−0.2	94	8	85	54	31	68	25	69	65	71	3.53	−1.3	13	5,876	s.	34	s.	4	18	10	3	3.4	0.0	0.0
Iola	984	11	50	28.94	29.94	−.03	80.4	+2.3	103	8	92	53	31	69	32				2.24	−1.7	7	3,948	s.	42	n.	29	8	12	11	5.5	0.0	0.0
Topeka	987	92	107				78.6	+0.8	103	1	89	52	31	68	29				3.44	−1.4	11	5,631	sw.	41	sw.	6	16	13	2	3.6	0.0	0.0
Drexel	1,299	10	54	28.59	29.95		75.4		101	1	87	48	28	64	33				3.68		8	5,475	s.	34	nw.	7	14	11	6	4.0	0.0	0.0
Lincoln	1,189	11	84	28.72	29.94	−.01	78.2	+1.7	103	1	89	50	31	62	29	66	60	58	2.07	−1.8	8	6,117	s.	58	n.	13	5	18	8	5.5	0.0	0.0
Omaha	1,105	115	122	28.80	29.95	.00	78.0	+1.3	104	1	88	54	31	68	33	66	60	58	0.45	−3.9	8	5,136	n.	44	n.	13	14	14	3	4.1	0.0	0.0
Valentine	2,598	47	54	27.32	29.99	+.06	73.3	−0.4	103	13	87	45	31	60	39	61	53	56	3.87	+0.5	11	6,024	n.	46	e.	26	15	14	2	3.4	0.0	0.0
Sioux City	1,135	94	164	28.78	29.96	+.01	75.6	+1.3	100	15	87	50	28	64	32	65	58	60	1.43	−2.2	5	7,117	s.	52	nw.	13	12	16	3	4.1	0.0	0.0
Huron	1,306	59	74	28.62	30.00	+.06	72.0	+0.2	100	12	85	47	22	59	35	62	56	61	2.02	−0.9	8	5,769	n.	42	nw.	13	16	13	2	3.6	0.0	0.0
Pierre	1,572	70	75	28.36	29.99	+.06	73.9	−1.4	103	10	86	51	31	62	35	63	56	59	2.77	+0.4	9	5,883	nw.	52	nw.	25	16	14	1	3.5	0.0	0.0
Yankton	1,233	49	57	28.67	29.96	+.02	74.8	+0.6	103	15	87	48	28	62	35				0.59	−2.9	6	4,114	n.	48	nw.	13	11	16	4	4.7	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, July, 1925*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01, or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
Northern Slope							**69.8**	**+2.0**										**54**	**1.46**	**−0.2**										**3.7**		
Billings	3,140	5					72.4		103	14	89	44	31	56	52				1.90		7		nw.				20	3	8		0.0	0.0
Havre	2,505	11	44	27.40	29.99	+.08	69.1	+0.8	99	11	84	40	8	54	43	57	48	56	1.45	−0.5	7	4,007	e.	36	sw.	12	19	10	2	2.8	0.0	0.0
Helena	4,110	87	112	25.87	29.97	+.04	70.1	+4.4	97	11	84	49	25	56	40	55	44	46	0.73	−0.3	6	5,656	sw.	37	sw.	17	14	13	4	3.8	0.0	0.0
Kalispell	2,973	48	56	26.94	29.93	.00	68.4	+4.3	93	10	84	45	19	53	42	55	45	51	0.58	−0.3	4	4,363	nw.	29	nw.	24	19	11	1	2.9	0.0	0.0
Miles City	2,371	48	55	27.53	30.02	+.10	73.0	+0.1	105	14	86	50	31	60	42	59	50	51	0.46	−0.9	7	4,129	se.	33	sw.	17	20	9	2	2.8	0.0	0.0
Rapid City	3,259	50	58	26.69	30.03	+.10	70.9	−0.1	96	13	83	45	31	59	31	59	52	56	2.58	0.0	12	5,144	w.	36	nw.	17	13	16	2	4.1	0.0	0.0
Cheyenne	6,088	84	101	24.16	29.99	+.07	68.0	+1.3	95	14	80	46	31	56	36	55	47	54	3.80	+1.8	13	7,515	s.	48	nw.	17	10	11	10	5.4	0.0	0.0
Lander	5,372	60	68	24.77	29.99	+.07	70.0	+2.6	100	14	84	50	31	56	40	55	46	49	1.57	+0.7	9	3,854	w.	36	nw.	19	10	15	6	4.8	0.0	0.0
Sheridan	3,790	10	47	26.19	30.02		69.4		105	14	86	42	31	53	53	58	51	60	0.96		6	2,754	s.	34	nw.	17	16	14	1	3.2	0.0	0.0
Yellowstone Park	6,241	11	48	24.03	30.03	+.11	62.5	+1.0	90	14	77	41	26	48	38	51	44	58	1.04	−0.1	13	5,029	s.	38	sw.	11	9	19	3	4.6	0.0	0.0
North Platte	2,821	11	51	27.14	30.00	+.07	76.2	+3.3	107	15	90	45	31	63	48	63	57	60	0.89	−1.8	6	4,290	e.	28	ne.	15	22	5	4	3.0	0.0	0.0
Middle Slope							**78.6**	**+1.5**										**59**	**3.09**	**+0.1**										**5.0**		
Denver	5,292	106	113	24.86	30.01	+.10	73.4	+1.2	99	15	84	53	31	62	30	58	49	51	0.74	−0.9	11	4,331	s.	38	n.	28	7	21	3	4.9	0.0	0.0
Pueblo	4,685	80	86	25.39	29.98	+.07	75.2	+1.0	102	18	88	53	31	63	36	60	54	59	3.78	+1.8	14	4,577	nw.	38	w.	19	4	21	6	5.4	0.0	0.0
Concordia	1,392	50	58	28.50	29.93	+.02	79.4	+1.4	103	7	91	51	31	68	32	67	61	60	3.13	−0.5	9	4,800	s.	33	n.	29	8	21	2	4.9	0.0	0.0
Dodge City	2,509	11	51	27.44	29.97	+.04	79.4	+1.0	104	18	91	50	31	68	32	66	60	60	6.84	+3.5	7	5,751	se.	46	ne.	29	17	10	4	3.6	0.0	0.0
Wichita	1,358	139	158	28.54	29.93	−.03	81.0	+1.6	100	1	92	54	31	70	29	69	63	61	1.72	−1.9	12	8,316	s.	50	w.	6	13	16	2	4.6	0.0	0.0
Broken Arrow	765	11	56	29.15	29.96		81.0		103	9	92	57	31	70	30				3.81		13	7,713	s.	45	se.	5	7	11	13	6.0	0.0	0.0
Oklahoma City	1,214	10	47	28.69	29.93	−.03	83.2	+2.6	104	9	94	60	31	72	30	70	64	61	2.35	−1.3	9	6,372	s.	27	s.	2	7	13	11	5.6	0.0	0.0
Southern Slope							**82.2**	**+1.4**										**53**	**3.22**	**+0.7**										**4.0**		
Abilene	1,738	10	52	28.17	29.92	−.01	85.0	+2.2	107	19	96	62	31	74	31	68	61	53	1.39	−1.0	7	6,307	s.	35	n.	14	10	14	7	5.2	0.0	0.0
Amarillo	3,676	10	49	26.32	29.95	+.03	78.4	+1.6	105	18	91	56	31	66	32	64	57	57	5.13	+2.0	13	6,918	s.	34	nw.	20	11	12	8	5.1	0.0	0.0
Del Rio	944	64	71	28.96	29.92	+.02	86.0	+1.3	101	15	96	70	12	76	27				2.32	+0.1	4	7,180	se.	44	e.	11	23	6	2	2.5	0.0	0.0
Roswell	3,566	75	85	26.39	29.90	+.02	79.6	+0.7	104	19	92	58	31	67	33	63	53	50	4.02	+1.8	9	5,157	e.	36	e.	3	20	9	2	3.4	0.0	0.0
Southern Plateau							**80.5**	**+1.5**										**47**	**0.90**	**−0.3**										**3.4**		
El Paso	3,778	152	175	26.20	29.88	+.04	82.4	+1.3	103	19	94	60	31	71	31	64	53	44	1.40	−0.7	8	7,192	nw.	48	w.	27	11	19	1	3.9	0.0	0.0
Santa Fe	7,013	38	53	23.40	29.91	+.03	69.8	+0.8	92	15	82	53	31	58	33	55	47	53	2.48	−0.2	17	4,365	ne.	25	sw.	27	5	20	6	5.5	0.0	0.0
Flagstaff	6,907	10	59	23.49	29.89	+.06	66.4	+1.4	92	15	81	44	5	52	39	52		54	1.83		12	5,011	w.	25	w.	21	9	18	4		0.0	0.0
Phoenix	1,108	10	82	28.68	29.79	+.01	92.7	+2.9	118	16	106	69	6	80	37	72	62	41	0.03	−1.0	3	3,783	w.	37	ne.	18	15	14	2	3.5	0.0	0.0
Yuma	141	9	54	29.64	29.78	+.02	92.3	+1.5	116	16	107	68	5	78	39	72	62	43	0.17	0.0	4	4,009	sw.	30	se.	15	28	2	1	1.5	0.0	0.0
Independence	3,957	5	25				79.2	+1.1	106	13	97	53	24	62	46	56			0.43	+0.3	9		nw.				15	12	4	2.8	0.0	0.0
Middle Plateau							**75.4**	**+3.0**										**40**	**1.33**	**+0.8**										**3.7**		
Reno	4,532	74	81	25.52	29.92	+.05	73.3	+5.8	102	14	90	48	23	56	48	55	44	44	0.97	+0.7	5	4,649	w.	34	se.	16	22	5	4	2.6	0.0	0.0
Tonopah	6,090	12	20				74.4		96	16	86	52	4	63	30	54	39	33	0.62		4		se.								0.0	0.0
Winnemucca	4,344	18	56	25.65	29.95	+.05	74.4	+3.8	104	14	92	47	26	57	50	55	43	43	1.22	+1.0	7	4,103	sw.	38	s.	20	17	9	5	3.4	0.0	0.0
Modena	5,479	10	43	24.70	29.92	+.06	72.0	+1.4	98	13	88	47	24	56	42	54	40	42	1.38	+0.1	10	6,857	w.	49	w.	19	17	11	3	3.9	0.0	0.0
Salt Lake City	4,360	163	203	25.65	29.92	+.02	78.8	+3.1	103	14	90	60	20	67	30	59	46	38	2.13	+1.6	7	5,030	s.	47	sw.	21	19	7	5	3.4	0.0	0.0
Grand Junction	4,602	60	68	25.44	29.95	+.06	78.7	+1.0	105	15	92	58	21	65	38	59	47	40	0.97	+0.5	9	4,165	se.	56	nw.	21	9	15	7	5.1	0.0	0.0
Northern Plateau							**76.1**	**+5.1**										**40**	**0.78**	**+0.3**										**2.5**		
Baker	3,471	48	53	26.48	29.99	+.04	70.4	+4.8	98	16	86	44	25	54	40	55	45	48	0.79	+0.4	4	4,254	se.	34	s.	16	20	10	1	2.7	0.0	0.0
Boise	2,739	78	86	27.14	29.92	−.01	78.0	+5.1	107	16	94	53	25	62	38	58	43	36	0.37	+0.2	2	3,297	se.	21	w.	24	24	6	1	2.2	0.0	0.0
Lewiston	757	40	48	29.11	29.93	−.02	80.3	+6.3	106	31	97	56	19	63	43				0.15	−0.3	3	2,604	e.	26	nw.	17	23	8	0	2.5	0.0	0.0
Pocatello	4,477	60	68	25.53	29.94	+.02	74.1	+3.3	104	14	89	49	1	60	43	57	45	47	3.33	+2.7	9	5,535	se.	48	sw.	22	14	12	5	4.0	0.0	0.0
Spokane	1,929	101	110	27.94	29.93	−.03	74.9	+5.9	100	16	90	52	19	60	39	56	41	36	0.07	−0.6	1	3,732	s.	30	s.	24	23	6	2	2.5	0.0	0.0
Walla Walla	991	57	65	28.88	29.92	−.05	79.0	+5.0	104	31	93	57	8	65	38	60	45	34	T.	−0.4	0	3,407	w.	18	sw.	6	27	4	0	1.3	0.0	0.0
North Pacific Coast Region							**63.8**	**+1.7**										**63**	**0.18**	**−0.5**										**4.3**		
North Head	211	11	56	29.89	30.12	+.04	56.4	−0.8	65	13	60	50	3	53	9	55	53	91	0.22	−0.3	8	13,289	n.	52	s.	11	2	9	20	7.5	0.0	0.0
Port Angeles	29	8	53		30.10		58.2		73	9	67	43	18	50	25				0.05	−0.4	2	5,954	nw.	35	nw.	17	12	17	2		0.0	0.0
Seattle	125	215	250	29.97	30.10	+.06	65.0	+1.9	82	8	75	52	21	55	27	57	51	66	0.06	−0.6	1	5,007	nw.	23	sw.	28	18	11	2	2.9	0.0	0.0
Tacoma	194	172	201	29.88	30.08	+.02	65.2	+2.4	86	9	75	51	7	55	29				T.	−0.6	0	4,449	n.	24	w.	28	9	15	7	5.3	0.0	0.0
Tatoosh Island	86	9	53	30.01	30.11	+.06	54.7	−0.3	63	15	58	50	11	52	11	53	53	96	0.98	−0.8	8	7,703	s.	42	s.	11	4	9	18	7.4	0.0	0.0
Yakima	1,071	5					76.0		104	16	94	48	7	58	44				T.		0		nw.				22	9	0	2.5	0.0	0.0
Medford	1,425	4					75.4		106	16	95	50	8	56	48	58	48	46	T.		0		nw.	10	nw.	23	23	7	1		0.0	0.0
Portland, Oreg	153	68	106	29.88	30.04	−.01	69.8	+3.1	90	9	81	52	1	58	31	62	57	66	T.	−0.6	0	4,783	nw.	20	nw.	3	17	10	4	3.3	0.0	0.0
Roseburg	510	9	57	29.49	30.03	.00	71.4	+4.0	98	9	88	51	2	55	41	59	51	57	T.	−0.3	0	3,070	n.	15	n.	17	26	5	0	1.3	0.0	0.0
Middle Pacific Coast Region							**66.4**	**+1.6**										**66**	**0.03**	**0.0**										**4.1**		
Eureka	62	73	89	29.99	30.06	+.01	56.0	+0.5	67	12	60	47	8	52	15	53	52	89	T.	−0.1	0	4,416	nw.	25	sw.	4	2	13	16	7.1	0.0	0.0
Point Reyes	490	7	18	29.42	29.94		54.1	+0.4	65	18	58	47	2	50	14				0.07		1	13,134	nw.	67	nw.	28	1	7	23	8.5	0.0	0.0
Red Bluff	332	50	56	29.53	29.87	−.02	82.4	+1.6	113	17	98	56	24	67	40	63	50	40	0.00	0.0	0	3,289	se.	17	se.	10	27	3	1	1.1	0.0	0.0
Sacramento	69	106	117	29.82	29.89	+.01	75.4	+2.2	114	17	91	53	24	60	43	61	51	52	0.01	0.0	1	6,459	s.	25	sw.	18	25	6	0	1.3	0.0	0.0
San Francisco	155	208	243	29.80	29.97	+.02	61.2	+2.7	79	16	68	51	28	55	24	55	53	81	0.06	0.0	1	6,919	sw.	31	w.	7	11	14	6	4.4	0.0	0.0
San Jose	141	12	110	29.81	29.96		69.0	+2.1	97	17	82	50	29	56	35				0.02	0.0	1	4,694	nw.	24	sw.	21	26	4	1	2.3	0.0	0.0
South Pacific Coast Region							**73.3**	**+2.2**										**62**	**0.04**	**0.0**										**2.4**		
Fresno	327	89	98	29.51	29.85	+.02	83.8	+1.7	114	17	100	58	11	68	38	62	46	31	0.14	+0.1	1	5,904	nw.	24	nw.	12	29	1	1	1.1	0.0	0.0
Los Angeles	338	159	191	29.57	29.93	+.03	72.2	+2.0	97	17	82	57	6	63	27	64	60	73	T.	0.0	0	3,924	sw.	15	sw.	15	22	9	0	2.4	0.0	0.0
San Diego	87	62	70	29.84	29.93	+.01	70.2	+3.0	88	14	75	62	12	66	20	64	61	76	T.	0.0	0	4,836	w.	34	s.	13	20	10	1	3.1	0.0	0.0
San Luis Obispo	201	32	40	29.77	29.98	+.03	66.9	+2.2	99	13	78	49	29	55	45	57	52	68	T.	0.0	0	3,119	nw.	15	s.	17	18	13	0	2.9	0.0	0.0
West Indies																																
San Juan, P. R	82	9	54	29.93	30.02		79.1	−1.0	88	13	84	72	3	74	14				6.65	+0.2	20	8,774	e.	35	e.	5	10	15	6	5.2	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	29.73	29.85	+.01	80.3	0.0	93	27	87	71	21	74	18	75	75	91	3.83	−3.4	20	4,785	nw.	22	nw.	6	0	10	21	7.6	0.0	0.0
Colon	36	7	97	29.82	29.86	.00	80.8	+0.5	89	27	86	73	4	76	14	77	76	90	21.08	+5.3	30	6,386	sw.	25	w.	8	0	4	27	8.7	0.0	0.0
Alaska																																
Juneau	80	11	54				55.7		78	22	62	46	21	50	29	53	51	86	7.61		17	3,827	s.	28	se.	7	6	3	22	7.9	0.0	0.0
Hawaiian Islands																																
Honolulu	38	86	100				77.2		85	17	82	69	16	72	14	69	66	70	0.67	−0.5	15	6,332	e.	27	ne.	28	13	16	2	4.1	0.0	0.0

TABLE 2.—*Data furnished by the Canadian Meteorological Service, July, 1925*

Station	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*In.*	*In.*	*In.*
St. Johns, N. F	125												
Sydney, C. B. I	48												
Halifax, N. S	88												
Yarmouth, N. S	65												
Charlottetown, P. E. I	38												
Chatham, N. B	28												
Father Point, Que	20	29.79	29.81	−0.04	56.7	−0.9	63.3	50.1	85	42	7.36	+4.32	0.0
Quebec, Que	296	29.56	29.88	−.03	65.5	0.0	73.7	57.3	82	49	4.53	+0.27	0.0
Montreal, Que	187	29.66	29.86	−.07	67.3	−1.2	75.7	59.0	85	51	4.30	+0.01	0.0
Stonecliffe, Ont	489												
Ottawa, Ont	236	29.63	29.89	−.05	66.4	−3.1	77.0	55.9	88	47	4.84	+1.37	0.0
Kingston, Ont	285	29.60	29.90	−.07	65.8	−2.4	73.3	58.3	81	50	2.87	−0.02	0.0
Toronto, Ont	379	29.51	29.90	−.07	67.5	−0.5	77.0	58.0	88	46	3.51	+0.59	0.0
Cochrane, Ont	930				58.8		69.3	48.3	80	40	4.25		0.0
White River, Ont	1,244	28.58	29.87	−.07	58.0	−1.5	70.5	45.6	83	34	5.70	+2.90	0.0
Port Stanley, Ont	592												
Southampton, Ont	656	29.22			62.2	−2.5	71.2	53.2	84	41	2.82	+0.84	0.0
Parry Sound, Ont	688	29.22	29.90	−.06	63.6	−2.4	73.8	53.4	89	45	1.97	−0.65	0.0
Port Arthur, Ont	644	29.22	29.92	−.02	62.8	+0.8	72.9	52.8	92	41	2.46	−1.02	0.0
Winnipeg, Man	760												
Minnedosa, Man	1,690	28.19	29.97	+.04	63.2	+1.0	74.7	51.6	90	41	0.58	−2.02	0.0
Le Pas, Man	860				61.9		74.3	49.6	89	35	3.47		0.0
Qu'Appelle, Sask	2,115	27.76	29.98	+.06	63.9	+0.4	77.8	50.0	94	34	1.03	−1.45	0.0
Medicine Hat, Alb	2,144	27.67	29.87	−.03	70.2	+2.4	84.2	56.2	99	45	1.32	−0.77	0.0
Moose Jaw, Sask	1,759				65.4		80.1	50.7	99	40	1.45		0.0
Swift Current, Sask	2,392	27.49	29.96	+.05	66.7	+0.2	81.9	51.4	98	39	1.79	−0.65	0.0
Calgary, Alb	3,428												
Banff, Alb	4,521												
Edmonton, Alb	2,150	27.70	29.94	+.04	62.5	+1.9	75.4	49.6	87	39	1.69	−1.34	0.0
Prince Albert, Sask	1,450	28.45	30.00	+.09	64.2	+2.3	76.9	51.6	92	41	2.52	+0.47	0.0
Battleford, Sask	1,592	28.29	30.00	+.10	65.2	+0.5	78.7	51.7	93	42	1.98	−0.36	0.0
Kamloops, B. C	1,262												
Victoria, B. C	230	29.82	30.07	+.02	59.8	−0.2	67.7	51.9	75	49	0.16	−0.24	0.0
Barkerville, B. C	4,180												
Triangle Island, B. C	680												
Prince Rupert, B. C	170												
Hamilton, Ber	151	30.01	30.16	+.02	79.4	+0.7	85.6	73.3	90	68	6.53	+2.09	0.0

Chart I. Tracks of Centers of Anticyclones, July, 1925. (Inset) Departure of Monthly Mean Pressure from Normal

Chart I. Tracks of Centers of Anticyclones, July, 1925. (Inset) Departure of Monthly Mean Pressure from Normal
(Plotted by Wilfred P. Day)

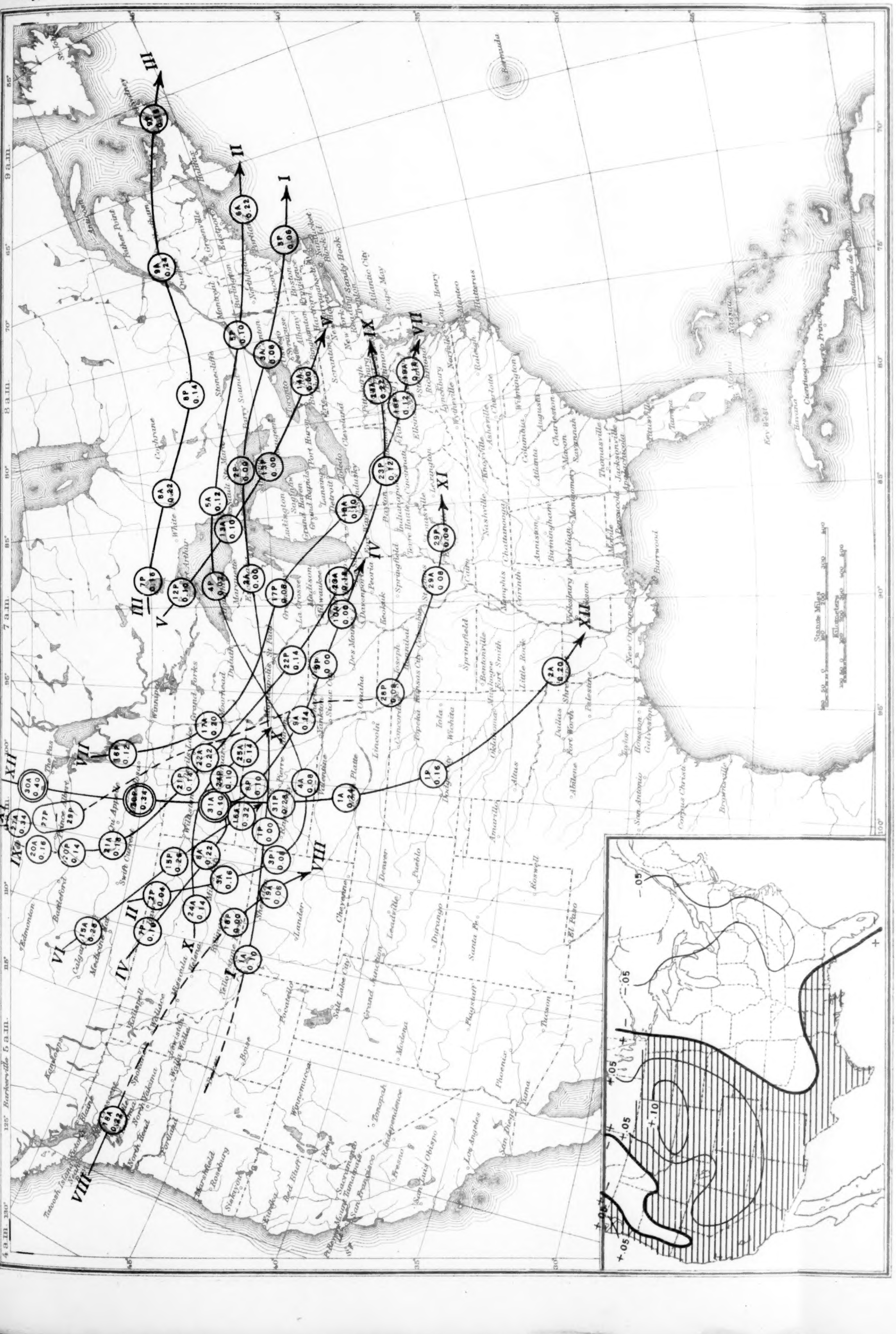


Chart II. Tracks of Centers of Cyclones, July, 1925. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day)

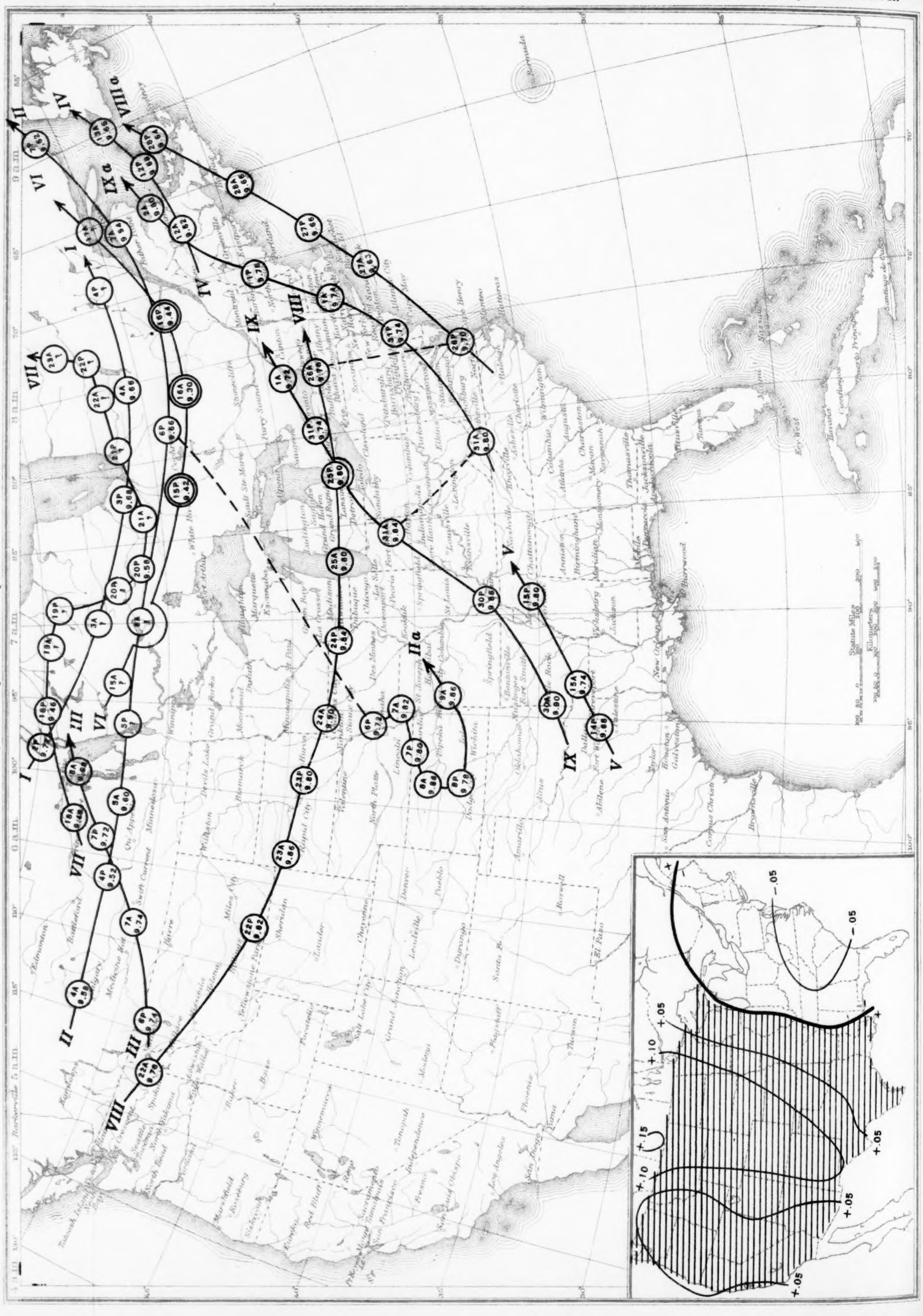


Chart III. Departure (°F.) of the Mean Temperature from the Normal, July, 1925

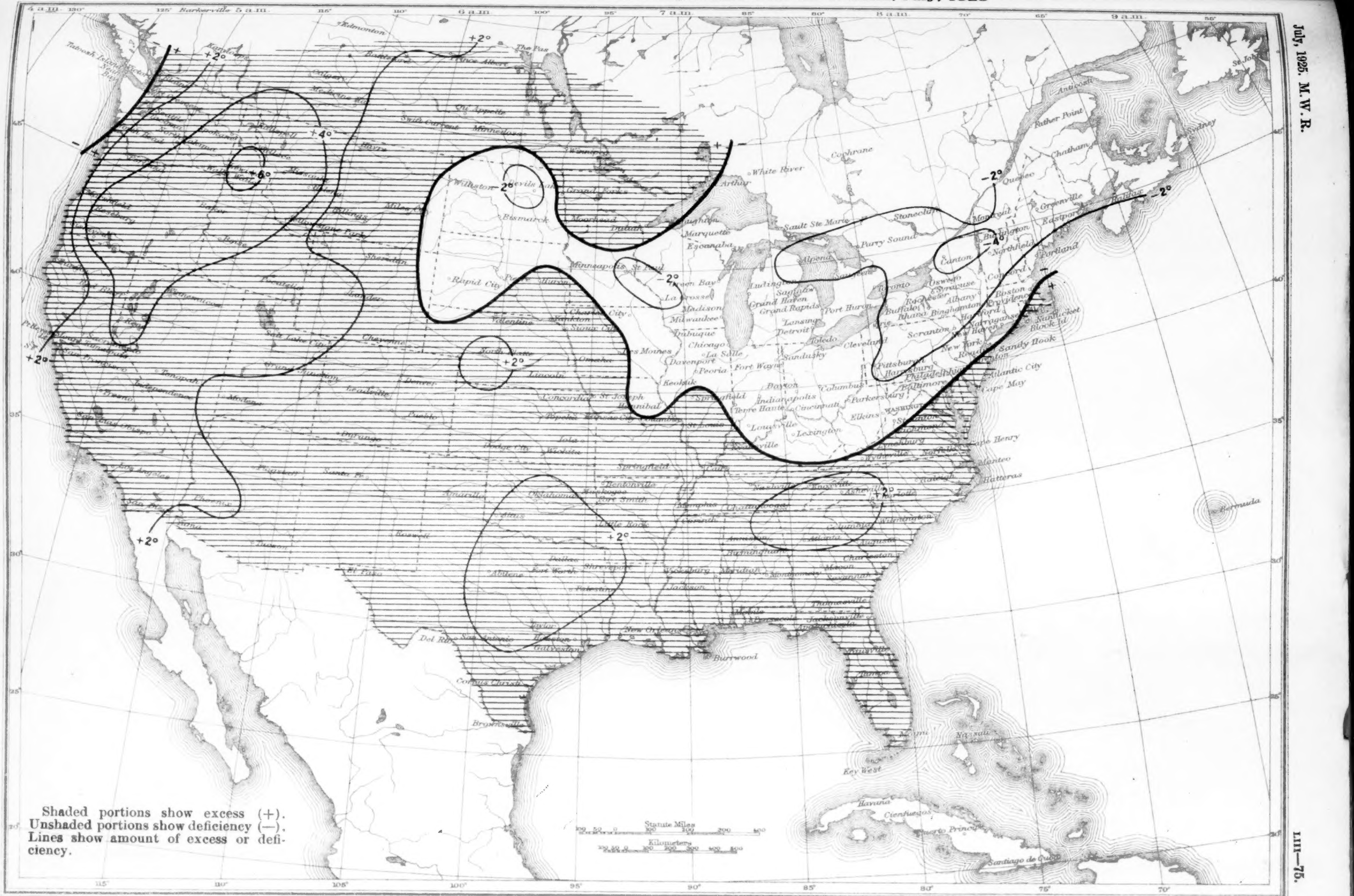


Chart IV. Total Precipitation, Inches, July, 1925. (Inset) Departure of Precipitation from Normal

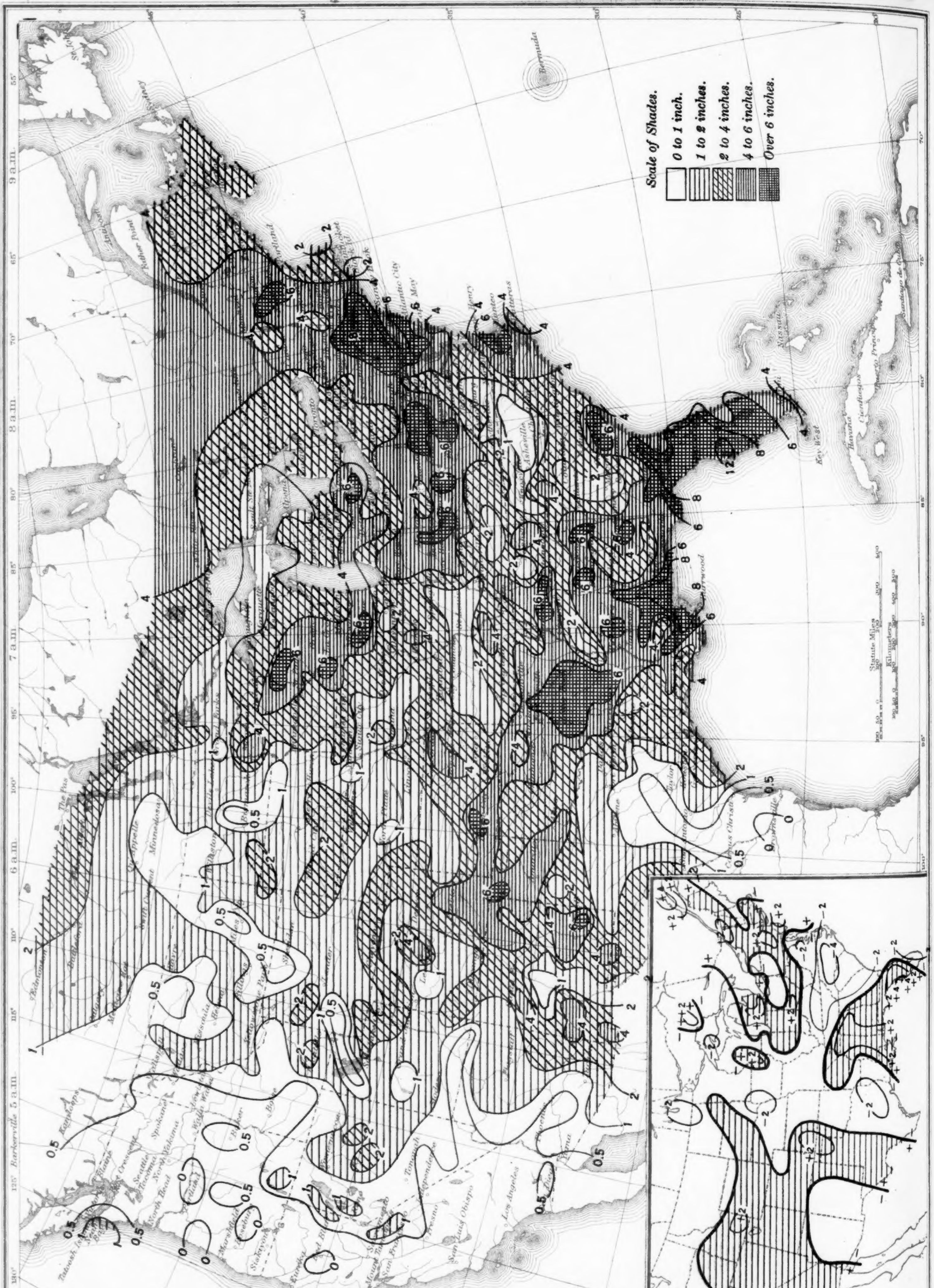


Chart V. Percentage of Clear Sky between Sunrise and Sunset, July, 1925

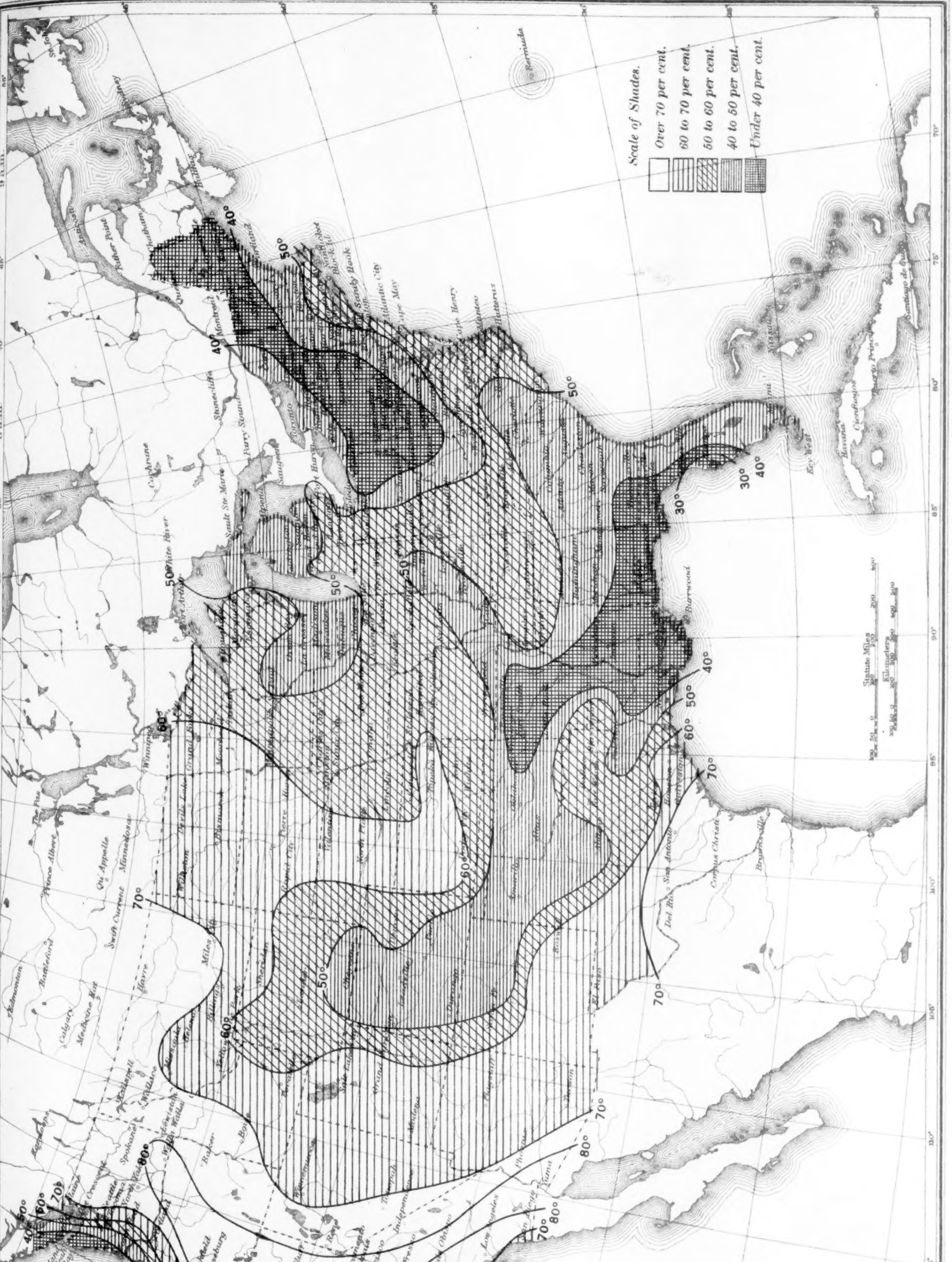


Chart V. Percentage of Clear Sky between Sunrise and Sunset, July, 1925

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, July, 1925